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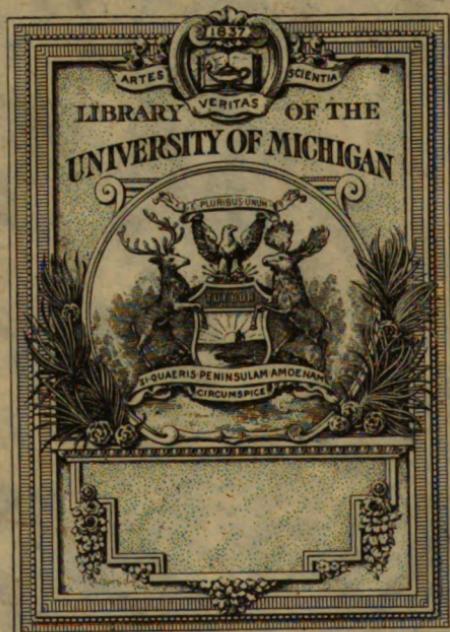
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**No. I.**

**1897**

**THE JOURNAL**  
1897  
**OF THE**

**IRON AND STEEL INSTITUTE**

**VOL. LI.**

**EDITED BY**

**BENNETT H. BROUGH  
SECRETARY**

**LONDON**

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IRON AND STEEL INSTITUTE.

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SECTION L  
*MINUTES OF PROCEEDINGS.*

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ANNUAL GENERAL MEETING.

THE ANNUAL GENERAL MEETING of the IRON AND STEEL INSTITUTE was held at the Institution of Civil Engineers, Great George Street, London, on Tuesday, May 11, 1897—Sir DAVID DALE, Bart., President, in the chair.

The SECRETARY read the Minutes of the previous Meeting, which were confirmed and signed.

Mr. HENRY WEBB and Mr. WILLIAM DRONSFIELD were nominated as Scrutineers, and on the completion of their scrutiny they reported that the following gentlemen had been duly elected as members of the Institute:—

NAME.	ADDRESS.	PROPOSERS.
Ash, Alfred . . . .	Great Bridge, Tipton, Staffordshire	Alex. E. Tucker, Sir B. Hingley, John E. Perry.
Brinell, I. A. . . .	Fagersta, Westanfors, Sweden	A. G. Ljungberg, George Senior, Albert Senior.
Campbell, Harry Huse	Steelton, Pennsylvania, U.S.A.	Andrew S. McCreathe, Henry M. Howe, Henry D. Hibbard.
Daniels, Fred. Harris.	112 Salisbury Street, Worcester, Mass., U.S.A.	J. P. Bedson, R. M. Daelen, E. J. Ljungberg.

## ELECTION OF MEMBERS.

NAME.	ADDRESS.	PROPOSERS.
Echevarria, José de .	Gran Via 2, Bilbao, Spain	W. Thomas, Herbert Eccles, Lewis Jenkins.
Evans, Evan David .	Penyrehol House, Merthyr	E. P. Martin, A. Bowen, Benj. Jones.
Flint, Henry . . . .	Park View, Wigan	Thomas M. Percy, John Smethurst, John Wood.
Griffin, Patrick Henry	Combe Wood, Bon- church, Isle of Wight	R. Schott, G. Senior, G. E. Hoyland.
Haehner, Paul . . . .	Bilbao, Spain	Edward P. Martin, A. Thielen, Sir Lowthian Bell.
Kensington, Frederick, M. Inst. C.E., M. Inst. Mech. E.	2 Copthall Buildings, London, E.C.	E. Windsor Richards, Wm. Radcliffe, James Riley.
Jenkins, David . . . .	Dowlais	E. P. Martin, A. Bowen, D. R. Jones.
John, David . . . .	Gwernlhoyn Uchaf, Dowlais	E. P. Martin, A. Bowen, W. Simons.
Jüptner von Jonstorff, Baron Hanns	Neuberg, Austria	Karl Wittgenstein, C. Ritter von Schwarz, P. Ritter von Tunner.
King, Henry Charles, M. Inst. Mech. E.	Engineer's Office, Loco. Dept., G. W. Rail- way, Swindon	William Dean, James Riley, Edward P. Martin.
Kosugi, Tatsuzo . . . .	Wood Bank, Dore, Sheffield	Alexander Wilson, Frederick Stubbs, Petronius Hodges.
Lazúrtegui, Julio de .	Bilbao, Spain	Sir David Dale, Sir Lowthian Bell, Edward P. Martin.
Lelong, M. . . . .	Couillet, Belgium	Alfred Maroquin, Sir Low- thian Bell, Sir David Dale.
Mendizabal, Carlos .	Sociedad de Altos Hor- nos, Bilbao	Sir David Dale, Sir Lowthian Bell, Edw. P. Martin.
Morgan, Gwyn Vaughan, B.A.	37 Harrington Gardens, London, S.W.	S. Vaughan Morgan, Edw. P. Martin, E. Windsor Richards.
Morgan, Penry Vaughan	13 The Boltons, Lon- don, S.W.	S. Vaughan Morgan, Edw. P. Martin, E. Windsor Richards.
Neilson, John . . . .	94 Hope Street, Glas- gow	E. P. Martin, Sir W. T. Lewis, David Evans.
Pearson, Louis Gaird- ner	Glengarnock Iron and Steel Works, Glen- garnock, N.B.	E. Windsor Richards, J. C. Cunningham, Edgar Wind- sor Richards.
Pernolet, Arthur . .	87 Rue Lafayette, Paris	C. Lowthian Bell, Henry Simon, Sir B. Samuelson.
Reddish, E. . . . .	Ganister Works, Atter- cliffe Road, Sheffield	E. Windsor Richards, George Senior, William Radcliffe.
Renny, Captain S. M., R.A.	Cossipore, near Cal- cutta, India	James Patchett, Sir B. Hing- ley, John H. Darby.
Sahlin, Carl . . . . .	Falun, Sweden	E. J. Ljungberg, A. G. Ljung- berg, Axel Molander.
Scott, Frederick Whit- taker	Reddish, Stockport	Alfred Muir, Charles R. Western, Henry Webb.
Sjögren, Arvid C. P. .	Avesta, Sweden	A. G. Ljungberg, George Senior, Albert Senior.
Smith, Peimberton, Assoc. M. Am. Soc. C. E.	18 St. Swithin's Lane, London, E.C.	Sir Wm. Anderson, Andrew Carnegie, Wm. Whitwell.

NAME.	ADDRESS.	PROPOSERS.
Stevens, John . . .	Ashby Road, Burton-on-Trent	Joseph H. Pearson, John D. Wragg, E. C. Keay.
Tempest-Radford, Thomas	Bevere Manor, near Worcester	Sir B. Hingley, Charles Akrill, Alex. McBean.
Thiry, Joseph . . .	Kohlendestillation in Bulmke, b/. Gelsenkirchen, Germany	W. H. Powell, Edwin Carlisle, John Crum.
Thomas, Wyndham .	Tin Plate Works, Abercarn, Mon.	Edw. P. Martin, A. T. Walker, E. R. Thomas.
Thorburn, William .	Guarnizo, Province of Santander, Spain	James G. Jenkins, James Riley, James Addie.
Tigerstedt, Axel Fredrik, M.A.	Industristedelen, Helsingfors, Finland	Alex. Wilson, F. Stubbs, Petronius Hodges.
Wainford, Richard Hanbury	120 Shirebrook Road, Sheffield	Samuel Thorpe, Thos. Black, E. Dickinson.
Warlow, Frederick Arthur	6 Kenwood Road, Sheffield	R. Woodward, Alfred E. Wells, R. Heber Radford.
Williams, Philip . . .	Park House, Blaenavon, Mon.	Edw. P. Martin, John R. Wright, Isaac Butler.

The SECRETARY then read the following Report of the Council upon the proceedings of the Institute during the year 1896 :—

## REPORT OF COUNCIL.

At this twenty-eighth Annual General Meeting of the Iron and Steel Institute, the Council have the pleasure of presenting to the members their Report on the Proceedings of the Institute, and are glad to note that the condition of the Institute during the year 1896 remained one of healthy vitality and of continued prosperity.

### THE ROLL OF THE INSTITUTE.

The number of members on the roll of the Institute on December 31, 1896, was—

Honorary members . . . . .	7
Life members . . . . .	2
Ordinary members . . . . .	1466
Total . . . . .	<u>1475</u>

During the past year there have been added to the register eighty names, a number slightly above the average of the previous five years, as is shown by the following statistics :—

Year.	New Members.
1891 . . . . .	76
1892 . . . . .	55
1893 . . . . .	45
1894 . . . . .	114
1895 . . . . .	93
Average . . . . .	76

The Council have to congratulate several members of the Institute upon high distinctions obtained by them. Sir William Anderson has been appointed to be a Knight Commander of the Most Honourable Order of the Bath, and a Knighthood has been conferred upon Sir James Laing ; the German Emperor has conferred upon Mr. A. Thielen, Vice-President, the Cross of the Order of the Red Eagle ; Don Leandro Cubillo, Colonel of the Spanish Regiment of Artillery, has been awarded the White Cross of Military Merit ; and Mr. F. A. Krupp has been created a Life Member of the Upper House of the Prussian Diet.

During the year under review the Institute has suffered great losses by the death of several of its distinguished members, the following twenty-eight deceases of members having been reported :—

Allen, William Daniel (Sheffield)	.	.	.	October 24.
Barnett, Francis Thomas (Matabeleland)	.	.	.	May 1.
Bond, George (Chesterfield)	.	.	.	April 22.
Bråkenhjelm, Arthur (Stockholm)	.	.	.	January 18.
Brock, Aubrey (London)	.	.	.	November 28.
Brockbank, William (Manchester)	.	.	.	September 18.
Cleminson, James Lyons (London)	.	.	.	November 15.
Clerke, William John Bird	.	.	.	February 13.
Crowther, Clement (Kidderminster)	.	.	.	January 17.
Davy, Abraham (Sheffield)	.	.	.	January 25.
Dean, John William (Bala)	.	.	.	February 25.
Dowden, William George (Blaenavon)	.	.	.	November 12.
Galloway, John (Manchester)	.	.	.	December 16.
Gray, Matthew (West Hartlepool)	.	.	.	June 16.
Greathead, James Henry (London)	.	.	.	October 21.
Haniel, Hugo (Düsseldorf)	.	.	.	January 5.
Johnson, John Thewlis (Manchester)	.	.	.	January 15.
Kennard, Howard John (London)	.	.	.	August 8.
Little, George (Oldham)	.	.	.	July 30.
Lynam, Henry Middlemore (Stoke-on-Trent)	.	.	.	November 4.
Morgan, Octavius Vaughan (London)	.	.	.	February 26.
Neilson, Walter (Cambuslang)	.	.	.	April 17.
North, John Thomas (Eltham)	.	.	.	May 5.
Pease, Henry Fell (Darlington)	.	.	.	December 6.
Ramsden, Sir James (Furness Abbey)	.	.	.	October 19.
Shaw, William (Middlesbrough)	.	.	.	June 29.
Tait, James (Coxhoe)	.	.	.	June 11.
Weeks, Joseph D. (Pittsburg, U.S.A.)	.	.	.	December 26.

Of these, Sir James Ramsden was one of the original members of the Institute, and always took a warm interest in its welfare. He was elected member of Council in 1881, and vice-president in 1891. Mr. W. D. Allen was the Bessemer Gold Medallist of 1890. Particulars of the professional careers of the deceased members will be found in the obituary notices published in the Journal of the Institute.

In consequence of the non-payment of subscriptions, the names of fourteen gentlemen have been removed from the list of members, and there have been twenty-two resignations of membership.

## FINANCE.

The statement of accounts for the year 1896 is now submitted to the members by the Honorary Treasurer. It will be observed that the income during the year amounted to £3891, 12s. 11d., and the ordinary expenditure to £3171, 9s. 11d., which, with £1167, 5s. in respect of the Ormuz guarantee, makes a total expenditure of £4338, 14s. 11d.

The corresponding figures for the five previous years are appended:—

	Receipts.			Expenditure.		
	£	s.	d.	£	s.	d.
1891 . . .	3742	6	10	2767	6	11
1892 . . .	3627	3	5	3942	7	3
1893 . . .	3589	11	0	3899	15	2
1894 . . .	3749	3	3	3074	1	9
1895 . . .	4159	7	5	3088	6	7

The receipts for 1895 included, it will be remembered, £333, 12s. 6d. in respect of exceptional income. This sum was paid in cash by Messrs. Ballantyne, Hanson & Co., who had agreed to bear the cost (£528, 9s. 6d.) of volumes of the Journal stored at their works and destroyed by fire in 1891.

A gratifying feature of the receipts in 1896 is the increase in the sales of the Journal, the amount received being £229, 0s. 6d., as compared with £128, 19s. in the previous year.

## INVESTED FUNDS OF THE INSTITUTE.

In accordance with a Scheme of Conversion adopted by the North-Eastern Railway Company, a change has been made in the invested Funds of the Institute, particulars of which are given below:—

<b>A. £1500 North-Eastern Darlington 5½ per cent.</b>			
Stock, purchased at a cost of . . . .	£2298	7	0
<b>B. £1681 North-Eastern 1876 4 per cent. Preference Stock, purchased at a cost of . . . .</b>	1998	19	7
<b>C. £630 North-Eastern Darlington 5 per cent.</b>			
Stock, purchased at a cost of . . . .	1008	14	0
<b>D. £1546 Scinde, Punjab, and Delhi 5 per cent.</b>			
Stock, purchased at a cost of . . . .	1999	0	7
<b>£750 Great Indian Peninsula Railway 5 per cent. Stock, purchased at a cost of . . . .</b>	1267	6	0
<b>Total cost . . . .</b>	<b>£8572</b>	<b>7</b>	<b>2</b>

**A.** and **B.** These have been converted into £3744 North-Eastern Railway 4 per cent. Preference Stock.

**C.** This has been converted into £788 North-Eastern Railway 4 per cent. Guaranteed Stock.

**D.** This has since been compulsorily converted into an Annuity up till 1958, with a Sinking Fund to replace the amount of Stock, £1546.

#### MEETINGS.

Two general meetings were held as usual during 1896. The Spring Meeting was held on May 7th and 8th at the Institution of Civil Engineers, whose constant courtesy in providing accommodation deserves grateful acknowledgment.

The titles of the papers contributed to the Institute's proceedings were as follows:—

1. On the Ford and Moncur Hot-Blast Stove. By B. J. HALL.
2. On the Production of Metallic Bars of any Section by Extrusion at High Temperatures. By PERRY F. NURSEY.
3. On the Treatment of New Zealand Magnetic Iron Sands. By E. METCALF SMITH.
4. On the Making of the Middle Lias Ironstone of the Midlands. By EDWIN A. WALFORD.
5. On the Introduction of Standard Methods of Analysis. By Baron H. JÜPTNER von JONSTORFF.
6. On the Rate of Diffusion in Iron. By Professor W. C. ROBERTS-AUSTEN, C.B., F.R.S.
7. On Mond Producer Gas applied to the Manufacture of Steel. By JOHN H. DARBY.
8. Further Notes on the Hardening of Steel. By H. M. HOWE and ALBERT SAUVEUR.
9. Note on Mr. Howe's Researches on the Hardening of Steel. By F. OSMOND.
10. A Study of some Alloys with Iron Carbides, mainly Manganese and Tungsten. By J. S. DE BENNEVILLE.
11. On the Iron and Steel Industries of Spain. By DON PABLO DE ALZOLA.
12. On the Present Position of the Iron Ore Industries of Biscay and Santander. By W. GILL.
13. On Further Experience with the Walrand-Legenisel Process. By G. J. SNELUS, F.R.S.

14. On the Roasting of Iron Ores with a view to their Magnetic Concentration. By Professor H. WEDDING.
15. On the Manganese Ore Deposits of Northern Spain. By J. HEAD.
16. On the Presence of Fixed Nitrogen in Steel. By F. W. HARBORD and T. TWYNAM.
17. On Sand on Pig Iron, and its Avoidance. By H. D. HIBBARD.
18. On the Missing Carbon. By T. W. HOGG.
19. On a Water-Cooled Hot-Blast Valve. By W. COLQUHOUN.
20. On the Estimation of Sulphur in Iron Ores. By R. W. and A. J. ATKINSON.

The international character of the proceedings of the Iron and Steel Institute is well shown in this list, in which it will be noticed that of the twenty papers three have been contributed by American metallurgists, and others by Colonial, Austrian, French, German, and Spanish metallurgists.

The Autumn Meeting was held in Spain, a country not previously visited by the Institute. The members were received with magnificent hospitality by an influential Local Committee, and the people of Bilbao and Santander, and the metallurgists of Spain generally, vied with one another to afford to the members of the Institute all the instruction and hospitality possible. To Don Tomas de Zubiria, Don Luis M. de Aznar, Don Ramon de la Sota, Don Julio de Lazurtegui, and Mr. William Gill, the members of the Executive Committee, the warmest thanks for the arrangements are due. The excursions which formed part of the meeting were most instructive and enjoyable, and have been described at length in the Journal of the Institute. Subsequent to the meeting the Council arranged for the presentation of specially bound copies of the Journal containing the report of the meeting to the members of the Local Reception Committee, and of albums containing the photographs and autographs of the members of Council to the Executive Committee, as souvenirs of a visit which, on account of the brilliancy of its success, the cordiality of the reception, and the warmth of the hospitality, is not likely soon to be forgotten by the members. Some difficulty was encountered in arranging for the transport of the members to Spain, and for their hotel accommodation during their stay in that country; for, in spite of the great increase in size of the Biscayan capital, the hotel accommodation was found to be insufficient to bear the addition of several hundred visitors at a time when Bilbao and the adjacent sea-side resorts were crowded with summer guests. It was,

therefore, decided to charter a special ship to convey the members and to serve as a floating hotel during the meeting ; and the Orient Steam Navigation Company, to whom the service of providing a ship was entrusted, selected one of the finest vessels of its fleet, the R.M.S. *Ormuz*, for the commission.

The Annual Dinner of the members of the Institute was held on May 7, 1896, at the Freemasons' Tavern. In the absence of the president, the chair was taken by Sir James Kitson, Bart., M.P., Past-President ; and there was a very large attendance of members and their friends.

#### PUBLICATIONS.

Of the Journal of the Institute two volumes have, as usual, been published, containing together 1107 pages of letterpress and 64 plates. In addition to the papers read before the Institute, and the discussion and correspondence relating to them, the volumes contain abstracts of 1136 papers relating to iron and steel and kindred subjects published in other home and foreign technical journals and transactions.

In view of the fact that the Journal of the Institute just issued was the fiftieth volume published, the Council have instructed the secretary to prepare a general index to the fifty volumes. The preparation of the index is making satisfactory progress, and it is hoped that it will be completed in time to be issued to the members with the second volume of the Journal for 1897.

#### LIBRARY.

Numerous presentations to the Library have been made, a list of which is given in the Journal of the Institute. For these the Council record their thanks to the several donors. Members who have published works valuable for reference, or pamphlets on subjects relating to iron and steel, of which they could present copies, are reminded that such contributions to the Library are highly acceptable for permanent preservation. The Council has purchased for the Library a complete set of the valuable publications of the *Société de l'Industrie Minérale*, and additional book-shelf accommodation has been provided to meet the growth of the Library.

The additions to the collection of portraits include a portrait of the late Mr. William Menalaus, past-president, presented by Sir William Thomas Lewis, Bart., Member of Council, and portraits of Mr. Josiah T. Smith, past-president, and of Professor Wedding, Bessemer Gold Medallist,

presented by these gentlemen. A family group of Sir Henry Bessemer, his son, his grandson, and his great-grandson, each named Henry Bessemer, has also been presented to the Institute by Sir Henry Bessemer, past-president.

#### INTERNATIONAL ASSOCIATION FOR TESTING IRON AND STEEL.

In order to obviate the great divergencies in the methods of testing iron and steel and other structural materials, International Congresses were held in 1884 at Munich, in 1886 at Dresden, in 1890 at Berlin, in 1893 at Vienna, and in 1895 at Zurich. A detailed report of the last Congress was communicated to this Institute by Professor George Lunge, and published in the Journal, 1895, No. II. p. 310. At this Congress it was decided to convert the loose organisation of these Congresses into a more stable body, to be termed the International Association for Testing Technical Materials. The object of the Association is the unification of methods of testing. Candidates must be proposed by two members, and the annual subscription is four shillings. In order to show the interest taken by the Institute in this undertaking, the Council has decided to pay an annual subscription to it of £5, and to send a delegate to the next Congress, with a view to publishing a report of the proceedings in the Institute Journal.

One of the decisions already arrived at by the Association is to found in Switzerland an International Research Laboratory for Iron and Steel. The necessary building has been supplied by the local authorities in Zurich, and Baron Jüptner, whose paper, read before the Iron and Steel Institute last May, indicated the desirability of such a laboratory, has been selected to direct the undertaking. All that is now required is an income of £1800 for ten years for the maintenance of the laboratory and for the payment of salaries. This sum should, it is thought, be contributed by the various countries in proportion to their iron production. In this way Great Britain's share would be £325 annually, and while it is not within the power of the Institute to make a specific grant, the Council trust that individual members of the Institute will do what they can to further an undertaking of great importance to the world's iron industry.

#### THE BESSEMER GOLD MEDAL.

The Bessemer Medal for 1897 has been awarded to Sir Frederick Augustus Abel, Bart., K.C.B., D.C.L., D.Sc., F.R.S., Past-President, in recognition of his services towards the advancement of the metallurgy of iron and steel.

## RETIRING MEMBERS OF COUNCIL.

The retiring members of Council are :—

*Vice-Presidents.*

Sir J. G. N. Alleyne, Bart.                    Mr. James Riley.  
    Mr. G. J. Snelus, F.R.S.

*Members of Council.*

Mr. W. Beardmore.                            Mr. R. A. Hadfield.  
Sir Benjamin Hingley, Bart.                Sir Wm. Thomas Lewis, Bart.  
    Mr. S. R. Platt.

As no other candidates have been nominated, these gentlemen, who are all eligible, are presented by the Council for re-election.

The Treasurer (Mr. WILLIAM WHITWELL) read the Annual Statement of Accounts for the year 1896 (p. 12).

**STATEMENT OF ACCOUNT.**

THE IRON AND STEEL INSTITUTE.

**STATEMENT OF ACCOUNT FOR THE YEAR ENDING DECEMBER 31, 1896.**

INCOME.		EXPENDITURE.	
Balance due from Treasurer, December 31, 1895		By Salaries	
Entrance Fees	£ 168 0	Office Rent, Cleaning, &c.	£899 10 0
Subscriptions	3131 2	" Library, Books, Building, &c.	335 12 8
Subscriptions in advance	31 10 0	" Office Furniture	83 12 2
Life-Composition	31 10 0	" Annual Meeting Expenses (London)	2 3
" Journal sales	229 6 6	" Autumn Meeting Expenses (Spain)	52 10 0
Interest on Investments	285 0 9	" Journal Publishing Expenses:—	1432 6 8
Bessemere Medial Fund Interest	15 9 8	Printing . . . . .	845 19 9
	<hr/>	Abstracts . . . . .	125 0 0
	<hr/>	Translations of Papers . . . . .	54 15 0
	<hr/>	Postage and Receipt Stamps . . . . .	85 15 10
	<hr/>	Printing and Stationery . . . . .	92 18 6
	<hr/>	Insurance . . . . .	243 5 3
	<hr/>	Bessemere Medial . . . . .	1 16 0
	<hr/>	Corporation Duty . . . . .	16 5 0
	<hr/>	Sundry Payments . . . . .	14 16 0
	<hr/>	Auditor's Fee . . . . .	89 0 0
	<hr/>	Bank Charges . . . . .	10 10 0
	<hr/>		4 1 2
	<hr/>		£4338 14 11

May 11, 1897.

**WILLIAM WHITWELL, Hon. Treasurer.  
BENNETT H. BROUGH, Secretary.**

INVESTED FUNDS OF THE INSTITUTE

£31,744 North-Eastern Railway 4 per cent. Preference Stock, purchased at a cost of £1,878 North-Eastern Railway 7 per cent. Guaranteed Stock, purchased at a cost of £15,144 Scinde, Panjab, and Dahl 6 per cent Stock, purchased at a cost of £7,650 Great Indian Peninsula Railway 5 per cent. Stock, purchased at a cost of	2,297 1,008 1,990 1,267	6 14 0 6
	2,8572	7

I have examined the above statement with the Books and Vouchers of the Institute, and certify it to be correct. I have also examined the securities for the Invested Funds as shown above, which appear to be in order, and I have verified the balance of the bankers' accounts.

W. B. KEEN, Chartered Accountant.

\* This has since been compulsorily converted into "B." annuities of £79 4s. 5d., expiring in 1958, with a Sinking Fund to replace the value of Stock.

The TREASURER said that the Secretary, the Auditor, and himself had examined the securities of the Institute at the Bank, and found that their value was eminently satisfactory, their total cost was £8572, and their present market value was £11,270. With regard to the receipts, there had been an increase on the previous year of £65, 18s. Od., and, as compared with 1894, of £142, 9s. 8d. There had been a falling off of eleven in the number of members elected during 1896, and consequently the receipts for the entrance fees had been somewhat decreased; but there had been an increase in the ordinary subscriptions. The receipts from Journal sales showed a very substantial increase, amounting to £100, 1s. 6d., equivalent to 79 per cent. over the previous year, which was highly satisfactory. It was interesting to be able to report that so many of the outside public were now purchasing copies of the Proceedings at 16s. a volume, with a view of adding to their libraries, clearly showing the interest taken in the Institute and the confidence felt in the character of the Proceedings. The expenditure had been of the ordinary character except in regard to the Autumn Meeting, which, as had been explained in the Report, had been necessarily heavy. There had been an increase of £50, 3s. 2d. in purchases for the Library, which, of course, represented capital expenditure. There had also been an increase in the cost of the translations of papers, owing to the number of foreign papers read at the Spanish meeting. It would probably be expected that he should say something in regard to the expenditure in connection with the visit to Spain. There were many circumstances that led to the loss connected with that visit. In consequence of the terrible accident off Cape Finisterre many persons who had intended to go to Spain by the steamship *Ormuz*, chartered for that purpose, were prevented from going. The circumstances of the case were somewhat disappointing, in spite of the careful organisation and arrangements for the Autumn Meeting. They could not blame themselves in any way for the result. They all regretted that the loss had been incurred, but they could point to the fact that none of the visits to other countries had been made without considerable expenditure and loss. But he would not call it a loss, because they gained far more than the cost. The American visit involved a deficit of about £1800, and the

expenses of the visits to other countries had been in excess of the receipts. The funds of the Institute, however, were at present in a very satisfactory state. The Council and the Treasurer had much pleasure in putting the figures before the members, feeling sure that they would approve of the manner in which the funds had been dealt with. He desired to congratulate the late Treasurer, Sir David Dale, for the admirable way in which he had invested the funds of the Institute which had led to so satisfactory a result.

The PRESIDENT said it was his duty to submit the usual formal resolution, "That the Report of the Council and the accounts submitted by the Treasurer be received and adopted." It was unnecessary, especially as there was much to be done in the morning's work, to enlarge upon either the Report or the accounts. They were both very full and clear, and had put the members in possession of adequate particulars of the Institute affairs.

Mr. JEREMIAH HEAD had great pleasure in seconding the resolution proposed by the President. It was satisfactory to find that the members were not falling off, and that they still were able to get a good supply of excellent papers, and that, generally speaking, the Institute was in a prosperous condition. He was sure that all who were accustomed to contribute papers would be delighted at the decision of the Council to publish an Index of the Proceedings. It had long been wanted, and would be a great help to all who were in the habit of studying the Journals of the Institute.

With regard to the accounts, he might perhaps be permitted to say a word or two from the standpoint of an ordinary member. The Honorary Treasurer had spoken somewhat apologetically about their having to some extent outrun the constable last year in consequence of the Spanish trip. He did not think that the Treasurer or the Council need concern themselves at all on that point. If the expenditure did exceed the income, it was only by a trifling sum—less than £500; and taking into account the fact that the securities of the Institute were worth some £3000 more than the sum they were put down at (which was no inconsiderable one), he thought they might flatter themselves that

they had a flywheel that would at least take up any little variations of that kind in the speed of their progress. Besides that, he understood (if he was correctly informed) that if they did spend over the Spanish trip something more than was anticipated, it was mainly due to the fault of the members themselves, or some of them, and not to that of the governing body. It was simply because a great many persons had sent in their names as likely to go, thereby encouraging the Council to enter into a guarantee, and because those members afterwards failed to fulfil their expectations. They had Scriptural authority for saying that the man who said he would go and did not go was more reprehensible than the man who, first saying he would not go, afterwards did go. He thought, therefore, that they could scarcely blame the Council for doing what the members had wished and encouraged them to do. He seconded with great pleasure the resolution proposed by the President.

Mr. JOHN F. WILSON inquired whether, in view of the increasing value of the invested stocks, there was any proposal to decrease the amount of subscriptions, or in some other way to prevent the piling up of money to an extent that was practically of very little use to the Institute. It seemed as if the income was more than was needful even for extraordinary years, and he should be glad to know if, at any rate with regard to the present members, some reduction might be made in the subscription, or whether the Council had any other proposals with reference to the amount of money that was now approaching a very considerable sum and practically doing very little good.

The PRESIDENT said the members would hardly be assembled where they were if the policy of accumulating funds had not been adopted by their hosts in the building in which they were met. He thought it would be some time before they need feel it a burden upon them to dispose of their accumulating income.

The motion was unanimously adopted.

Mr. E. RILEY said he had much pleasure in proposing, "That the most cordial thanks of the members of the Iron and Steel Institute be, and are hereby, tendered to the President and Council

for their services during the past year." Very little need be said upon such a resolution, because the members would all agree as to the admirable way in which the business of the Institute had been carried on. The very favourable position of their finances, and the records they had in the Journal, afforded sufficient evidence that the business of the Institute had been carried out in a manner that all must consider eminently satisfactory. The members certainly owed to the Council, and more especially to the retiring President, Sir David Dale, a deep debt of gratitude for their services during the past year.

Mr. F. W. HARBORD, in seconding the motion, said it was quite unnecessary to enlarge upon the services rendered by the Council to the Institute. The past year had been an exceptional one ; the task of Sir David Dale and his colleagues had been unusually arduous, and they were therefore specially entitled to the best thanks of the members.

The motion was unanimously adopted.

The PRESIDENT thanked the members on behalf of himself, the Council, and the Hon. Treasurer for the acknowledgment of their services during the past year. That appeared to him to be an appropriate time for saying that he had accepted the honourable but onerous position of President, conferred upon him by the members two years ago, with very great diffidence and sincere hesitation. That feeling arose from his apprehension that the importance of the office of President might to some extent suffer from its being placed in his hands, and that for two reasons. He felt that his past record was not one either of scientific attainments or of any practical achievements, such as had characterised the careers of his predecessors, some of them uniting both those qualifications ; and he also felt that the absence of that technical knowledge might prevent his doing justice to the discussions on the papers read at the General Meetings of the Society. Those feelings were only overcome by two considerations. One was that he fully recognised that the very important and honourable post of President of the Institute was being conferred upon him in recognition of services of a different character from those which

his predecessors had bestowed upon the community and upon the Institute. The members had been kind enough to recognise that his twenty-five years' services as Honorary Treasurer justified them in departing somewhat from their high standard of qualifications, and he therefore felt that this view overcame one of his objections. The other objection was met by the kind assurance from members of the Council, especially those who were now sitting by his side, that they would aid him in the performance of his duties, and he begged sincerely to thank them for the manner in which they had done so. He hoped that in vacating, as he was now about to do, the Presidential chair, he might be transmitting it without any abatement of the lustre and distinction that had hitherto attached to it. So far as there might be any slight abatement, he knew that it would be fully revived by his successor, and by a long line of future successors of as high distinction as those who had preceded him. It only remained for him to bear in mind the maxim of welcoming the coming and speeding the parting guest. He did not recall that maxim with a view of inciting the members with regard to the first part of it, for he was sure that their welcome would need no incitement at all, but in order to remind himself that he must not detain the meeting longer. The king was dead, and it was their duty to say, "Long live the King!"

The retiring President then vacated the chair, which was taken by the new President, EDWARD P. MARTIN, Esq.

Mr. EDWARD P. MARTIN said that, in taking the chair, his first duty would be to offer his best thanks for the honour that had been conferred upon him in electing him to fill the position of President of the Institute—a position which, having been filled by so many eminent men, he had extreme hesitation in accepting. Counting, however, upon the cordial support of the members of the Institute, he hoped that during his term of office he should not only maintain the position of the Institute, but also increase and extend its usefulness.

Calling forward Sir Frederick Abel, Mr. Martin presented him with the Bessemer Gold Medal, saying that it was the highest  
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honour within the power of the Council to award, and at the same time assuring him that the unanimous expression of goodwill with which it was accompanied was most sincere. Sir Frederick Abel's services to his country had more than once been recognised by his Queen, and his services to the science of metallurgy had been frequently recognised by the scientific societies of Europe, and the honours which he had so often received from them marked him out as a fit and proper person to receive the Bessemer gold medal.

Sir FREDERICK ABEL, Bart., Past-President, said that the kind and gracious words of the President accompanying the presentation of the medal which he had the honour to receive, and the award of which was to him one of the most gratifying incidents in the course of his career, added very greatly to its value. The eminent men who had received the medal in past years had almost all of them distinguished themselves by important practical achievements intimately connected with the advancement of the great industries which the Institute represented, and with which it was so closely identified. One or two of them had received that great distinction for work of purely scientific character, and it was a source of great pleasure, great pride, and of very unexpected satisfaction to himself to be associated in this way with those who had been thus specially distinguished. He referred more particularly to his old friend and colleague, Dr. Percy, and also to the last recipient, an intimate friend of Dr. Percy's, the talented translator of his classical work—Dr. Wedding. It was gratifying to men of science to know that, while the members of the Institute, especially in later years, themselves combined high scientific attainments with great practical knowledge, they still looked forward to and gladly recognised the assistance which could be afforded by men who worked purely for the advancement of science in the particular directions in which the Institute was specially interested. He heartily thanked the members for the honour they had done him.

The PRESIDENT then delivered his inaugural address.

## PRESIDENTIAL ADDRESS.

By EDWARD P. MARTIN, Esq.

IN taking this Chair my first duty is to offer you my best thanks for the honour you have conferred upon me by electing me to fill the important position of President of this Institute; a position which, having been filled by so many eminent men, I have accepted with hesitation. But counting upon your cordial assistance, I hope during my term of office not only to maintain the position of this Institute but also to extend and increase its usefulness and influence.

By a custom which has now become a rule, your President, in common with those of kindred institutions, is expected to deliver an inaugural address, and while there is a superabundance of matter upon which I might dwell that would certainly command your attention, the great difficulty is to select such subjects as would be interesting, and beneficial for the Institute.

But whatever difficulty I may experience in choosing matters of interest for such an address, I feel sure that although this Institute is cosmopolitan, the members will concur that in the exceptional circumstances of the Diamond Jubilee it is most fitting that I should in the first place allude to the fact that our Gracious Majesty, Queen and Empress Victoria, has, under God's providence, ruled to the great advantage of her country and subjects during a longer period than any other monarch, and is venerated and beloved in every part of the civilised world, the admiration of all nations and the pride of our own. Upon such an occasion it might have been appropriate to have attempted to recapitulate some of the improvements and inventions in connection with the manufacture of iron and steel that have occurred during her Majesty's long reign, but this would only have been an attempt to condense a great deal of what has already been recorded in the proceedings of this Institute.

## PAST AND PRESENT EXPERIENCE.

Having been identified all my life with one of the oldest iron-making districts in this country (one which may be referred to from an iron-making point of view as "classic ground") it has occurred to me that it would be useful on this occasion to recall some facts in connection with past experience, compare them with the present, and show what great improvements have been made, and thus, I hope, encourage all of us to endeavour to secure further progress and improvements in every department embraced in connection with the manufacture of iron and steel.

In the past, as in the present, one of the most important factors in manufacture was that of "fuel" and the best mode of using it economically. I find, by reference to the earliest records obtainable as to iron-making in South Wales, that in 1791 the quantity of coal consumed per ton of pig-iron at Dowlais averaged 8 tons 1 cwt., while the average make of pig-iron per furnace per week was 20 tons.

In 1821 the quantity of coal consumed had fallen to 4 tons of coal per ton of pig-iron, and in 1831 to 3 tons per ton of pig-iron, while the make per furnace per week had increased to 62 tons in 1821, and further increased to 78 tons by 1831. It was only as late as 1845 that the 18 blast furnaces working at Dowlais averaged 101 tons per furnace per week. Since then makes have improved and the amount of fuel has been reduced still further. In 1859 the average make was 137 tons per furnace per week. In 1870 it was 174 tons and in 1877, 260 tons; the consumption of coal in 1859 was  $2\frac{1}{2}$  tons, in 1870, 2 tons, and in 1877 remained about the same.

Twenty years later, in 1896, the maximum makes of the blast furnaces increased to upwards of 1600 tons per week, with a consumption of coke of about 19 cwt., or, say, equal to about  $1\frac{1}{2}$  tons of coal per ton of pigs.

I need hardly point out that these improvements have been due to various causes brought about by great changes in materials used; for as the works in the district increased, the supply of native ironstone became scarcer and more expensive to work, and these had to be supplemented by supplies of iron ore brought from

Llantrisant, the Forest of Dean, Lancashire and Cumberland. Later on other supplies of ore had to be obtained from the districts of Northamptonshire, Cornwall, Devonshire, and Ireland. The introduction of steel, however, created such a demand for ores free from phosphorus, that the chief sources of supply were soon restricted to the Cumberland and Lancashire districts and Bilbao. The Welsh ironstone mines, together with those in Cornwall and Devon, soon ceased to be worked, and during the last few years Dowlais, in common with other English ironworks, has practically been dependent upon Spain for its supply of this class of iron ore.

With this change in the ores for the manufacture of iron to that for the manufacture of steel, oven-coke was given up instead of raw coal. This caused the furnaces to drive faster and greatly increased the make of iron.

A comparison between the older outputs and those of the present day, affords some idea of the enormous advances which have been made during that period in iron and steel manufacture. Few, however, realise the cost which these changes have involved, and the losses new inventions have entailed upon iron manufacturers. The inventions of Bessemer and Siemens, much as they have benefited the world at large (paradoxical as it may appear), can scarcely be regarded as unmixed blessings by the older ironmasters, whose capital was invested in ironworks, the value of which in many instances has been reduced to that of the mere bricks and mortar.

The Dowlais Iron Company was, in 1856, one of the first to take a licence for working Bessemer steel, and it was at their works that Bessemer steel was first rolled into rails. The analysis of one of these rails, rolled in 1856, a piece of which is now in my possession and which I have recently analysed, gave the following results :

Carbon . . . .	0·080	Arsenic . . . .	trace
Silicon . . . .	trace	Manganese . . . .	trace
Sulphur . . . .	0·162	Iron . . . .	99·330
Phosphorus . . . .	0·428		

I have it on the authority of Sir Henry Bessemer himself that the pig-iron from which these ingots were made was grey Blaenavon, and it was converted into soft iron or steel, without

any addition of spiegel or manganese, the converter being lined with Stourbridge fire-bricks. The rails were rolled by my late esteemed friend and predecessor in this Chair, Edward Williams, from two ingots 10-inches square, made at the experimental works at Baxter House, London.

When Menelaus, Williams, and Edward Riley made their successful tests at Dowlais, immediately after Bessemer read his paper at Cheltenham, I have reason to believe, as the result of inquiries, that the iron they used was best foundry iron, made from a mixture of Welsh mine, Cumberland and Forest of Dean ores, containing much less phosphorus and sulphur than the usual run of pig-iron.

When Mr. Bessemer came to Dowlais to continue the experiments, a convenient refinery happened to exist opposite the furnace making cinder-pig, and the iron from this furnace was by a singular and most unfortunate mischance employed for Mr. Bessemer's trials. The results were most disappointing, and it was suggested at the time that such irregularities were inherent in the process. By accident I, some time ago, came upon one of these Bessemer ingots, which has been kept at Dowlais ever since the first experiments were made by Sir Henry Bessemer. This I have analysed, with the following results:

Carbon . . . .	0·06	Phosphorus . . . .	1·930
Manganese . . . .	nil	Arsenic . . . .	0·010
Silicon . . . .	0·01	Iron by difference . . . .	97·714
Sulphur . . . .	0·276		

This fully explains the cause of the failure of the process on that most important occasion, it not having been ascertained at that time that large quantities of sulphur and phosphorus were detrimental to the manufacture of Bessemer steel. It also explains why, although the Dowlais Iron Company was one of the first to take up a licence, they did not begin to roll steel rails until 1864.

It may, however, be of interest to mention that iron rails died hard, as they were rolled at Dowlais in large quantities until 1882, and that the substitution of Bessemer and Siemens' steel for the manufacture of rails, plates, and bars, in place of puddled iron, has now reduced the number of puddling furnaces at Dowlais from

255 to 15. When the recent extension of the Dowlais works was decided upon, Mr. Clark, the trustee, determined, as the native ironstone had ceased to be worked, and the coalfield had been drawn upon for nearly a century and a half, that the new works should be erected at Cardiff. By so doing, the cost of railway transit was greatly reduced, as the whole of the iron ore used there as well as a large portion of the finished material made is sea-borne.

In erecting this new plant, great attention has been given to diminishing labour cost as much as possible by the introduction of modern labour-saving appliances, and though the scale of wages paid at the new works is generally higher than in the northern part of the district, the labour cost per ton of pig-iron compares favourably.

At the Dowlais-Cardiff Works, iron ore can be discharged at the docks, passed through the blast furnaces, and the pig-iron made, treated by the Siemens process, and made into steel plates within forty-eight hours !

Concurrent with the various improvements that were introduced in connection with the Bessemer and Siemens processes, it may be mentioned that it was during the period of my management at Blaenavon that Messrs. Thomas and Gilchrist succeeded in working out there their important system of dephosphorising, in the years 1877 and 1878, a system for which our former President, Mr. E. Windsor Richards, did so much towards making a practical success.

With the exception of the inventions of Bessemer and Siemens, few improvements in the production of iron and steel have effected greater changes. Steel works which formerly depended on ores free from phosphorus, which had frequently to be brought long distances, were proved to be in close proximity to large supplies of cheap ores for steel making. In this country, this is especially the case in the Cleveland, and to some extent in the Northamptonshire and Lincolnshire districts, and will also apply to Staffordshire, Lancashire, and North Wales so long as the supply of forge cinders continues.

One of the most striking features in connection with steel manufacture is the great advance in the production of Siemens steel. The output of the Siemens furnace cannot compare with

that of the Bessemer converter, and to overcome this disadvantage several attempts have been made by Kupelweiser, Pernot, and others.

Attempts have also been made to increase outputs by charging molten iron, and by blowing air or steam into the bath. The results, however, when worked on a large scale, have been disappointing, and as a rule increased outputs have been attended with increased loss.

Arrangements for diminishing the time lost in charging are being brought under special notice both here and in America, and a paper dealing with this important subject will be read to-morrow by Mr. Head.

Mr. Gilchrist has directed attention to a system at work at Kladno, on which a paper will be read at this meeting, and it is hoped that this process will meet the anticipation of its inventors, both by increasing the output and by reducing cost.

#### STATISTICS.

It is satisfactory to be able to call attention to the following statistics as to the production of iron and steel in the United Kingdom during last year.

The make of pig-iron in 1895 was 7,895,675 tons, which increased in 1896 to 8,563,209, being the largest quantity ever produced in this country, the average make per furnace in blast in the United Kingdom being 23,682 tons.

The quantity of steel produced in Great Britain in 1896 was 4,133,397 tons, of which 1,815,842 tons was of Bessemer manufacture and 2,317,555 tons was of Siemens' manufacture.

The quantity of steel rails made in this country in 1896 was 847,534 tons, being an increase of 213,396 tons on the previous year, although unfortunately very far short of the maximum quantity of steel rails made in this country, which was in the year 1882.

The output of basic Bessemer steel increases slowly; in 1896 it was 457,262 tons, as compared with 441,550 tons in the previous year, and there is every probability that the basic process will make much more rapid progress in this country as imported ores become dearer.

The make of manufactured iron in the United Kingdom in 1895 was 1,148,012 tons; in 1896, 1,198,584 tons; an increase of 50,572 tons.

The exports of different classes of iron and steel manufactured in this country during the last two years were as follows:

	Iron and Steel.	Pig Iron.	Merchant Iron and Steel.	Wire, excluding Telegraph.	Plates and Sheets, exclusive of Tin-plates.	Tinplates.
	tons.	tons.	tons.	tons.	tons.	tons.
1895	2,835,000	866,568	143,990	42,220	338,500	366,120
1896	3,552,000	1,059,796	178,124	56,368	415,000	266,955
Increase	717,000	193,228	34,134	14,148	76,500	99,165 decrease.

#### FOREIGN PROGRESS.

While congratulating British manufacturers upon the statistics just mentioned I have to compliment our Continental competitors on the great progress they are still making in iron and steel manufacture.

During a recent visit to Westphalia and to the works on the German and French frontier, I was much impressed by the enterprise and large amount of capital being expended in bringing the works of those districts to a high state of efficiency.

Krupp is constructing entirely new works, on a large and complete scale on the Rhine, and De Wendel has recently erected large and important works at Hayange, where, instead of adopting what I would term the American or English plan of getting the utmost possible output from each mill, the works are laid out so as to accommodate themselves easily and conveniently to the varied demands of the market; so as with little expenditure or loss of time or material they are able to change from one class of work to another, from the manufacture of heavy girders in one mill

to sleepers, rails, or angles in another, the same workmen being employed at the different mills to turn out the respective classes of work required.

I do not wish for a moment to give countenance to the alarm which seems to have seized the public with regard to our industrial position and prospects. No doubt in 1851 our position was unique, and we then enjoyed a far larger proportion of the manufacturing trades of the world than we do at present; but the day has gone by for any monopoly of manufactures remaining in any single country, and we shall have to accommodate ourselves to those articles of manufacture for which our resources are best fitted.

The marvellous progress made in the American manufacture of iron and steel since Sir Lowthian Bell reported to this Institute in 1890, is another indication of the continued improvements in every department of metallurgy, and ought to stimulate us all to renewed efforts to place the works in this country upon the best possible footing.

#### AMERICAN COMPETITION.

The competition of America with Europe has advanced so much, especially recently, that I venture to refer to it at greater length than I should otherwise do.

The Carnegie Steel Company have again surprised the world by the tremendous strides they have made by the erection of the Duquesne furnace plant, which marks a new era in the history of blast furnaces. This plant has been laid out with a view of reducing labour and general expenses to a minimum, and of producing the largest outputs in the world.

The handling of very large quantities of traffic, the delivering of material into stock and taking it out with the least possible expense by machinery, have received special attention; and by the adoption of self-filling tubs combined with the old Lowmoor plan of delivering material on to the top and then into the blast furnace without manual labour, the labour cost has been reduced to a minimum.

The Duquesne furnaces hold the world's record; as with an

ore yielding from 57 per cent. to 60 per cent. of iron, the following are the recent makes and yields of these blast furnaces :

Best month's work . . . . .	17,182 tons, or 572 tons per day
Best week's work . . . . .	4110 tons
Best day's work . . . . .	690 tons
Best month's coke consumption . . . . .	1700 lbs. per ton of pig.

In this country with iron ores yielding 48 per cent. to 50 per cent. we look upon a make of a little over 1600 tons per week with a degree of satisfaction, but when this is compared with the gigantic outputs obtained from the Duquesne furnaces during the same periods, it must be admitted that the results achieved here leave much to be desired.

Notwithstanding the vast outputs already produced by the new furnaces at Duquesne it is expected that those in course of erection, which will be blown with 20 tuyeres in two rows of 10 placed above each other, will turn out the enormous quantity of 1000 tons per furnace per day.

The Bessemer Steel Works at Duquesne are on the same huge scale as the blast furnaces. They can deal with 500,000 tons of pigs a year, and can roll in the billet mill 1500 tons per twenty-four hours.

The output of rail-mills, wire-mills, and plate-mills are all equally astonishing.

At the Edgar Thomson works of the Carnegie Steel Co., upwards of 2000 tons of rails have been rolled in twenty-four hours.

At the Steel Works of the Illinois Co. the rail mill has produced 1025 tons of rails in twelve hours and a monthly make of upwards of 38,000 tons.

At the Joliet works of the Illinois Steel Company a Garrett wire rod mill has early this year made in one week the extraordinary output of 3273 tons of No. 5 wire rods. Since then the enormous make of 728 tons in twenty-four hours has been attained.

I am informed that the cost of manufacture and labour has been so reduced by these new mills that wire rods can now be made in the United States at a cost not exceeding 16s. per ton above the price of billets, including coal, labour, fuel, supplies

and repairs, and every expense connected with the manufacture. Of this 6*s.* is for labour.

#### FREIGHTS.

Nothing, perhaps, has tended more to bring about a greater change in the relative positions of works and markets than the reductions in the rates of freights. As an illustration it may be mentioned that in the short time which has elapsed since the opening of the mines at Bilbao, the freight of ore, which formerly was as high as 16*s.* or even 18*s.* a ton to the Bristol Channel ports, has since been reduced to less than 4*s.* per ton and is to-day about 4*s. 9d.* delivered.

But for this reduction in the cost of freight, the invention of Thomas and Gilchrist would practically have placed the iron and steel trades of the world in the hands of those having the command of abundant and cheap phosphoric ores, and it is this invention which has given the German and French ironmasters in the Minette ore districts the special advantages they possess.

#### IRON ORE SUPPLY.

The difficulty recently experienced in obtaining an ample supply of iron ores of good quality, has undoubtedly interfered to some extent with the output of hematite pig-iron; and although we imported last year a million more tons of foreign ore than during the previous year, the scarcity of ore is still felt. Notwithstanding this scarcity of mineral, the quantity of iron ore raised in this country has not appreciably increased, and the difficulty of getting an ample supply from Spain, the Mediterranean or the Scandinavian districts is, at present, engaging the attention of every maker of haematite-pig, not only in this country, but also in Belgium and Germany.

There cannot, however, be any doubt as to the enormous undeveloped deposits of iron ore of good quality in Spain, which can be made available for the iron trade, although at an increase of cost in the shape of freight to the sea coast.

The Minette district, on the borders of Germany and France, does not seem to have attracted the attention it deserves of British and American ironmasters. Its great importance, however, cannot

fail to be recognised when it is remembered that this district alone furnishes upwards of 10,000,000 tons of ore per annum, or nearly double the quantity worked in the important district of Cleveland, and I need hardly point out that the advantages possessed by works that can be supplied with this cheap ore are such as must undoubtedly tell in the great race of international competition for the markets of the world.

Reverting again to advantages enjoyed by the United States, it is difficult to over-estimate the value of the discovery of ore in the Mesabi range where the quantity of iron ore already proved in these mines is estimated at the enormous figure of 300,000,000 tons, practically an inexhaustible supply even for American demands.

Every convenience and labour-saving appliance is adopted for the extraction and loading of the ore into waggons and vessels, and the following is an estimate of the lowest cost at which Mesabi ore can be raised and delivered at Cleveland :

	s. d.
Extraction . . . . .	1 0½
Royalty . . . . .	1 0¼
Transport to Duluth . . . . .	3 4
" Cleveland . . . . .	2 11
Total . . . . .	<u>8 4</u>

To this has to be added the cost of transport from Ashtabula or Cleveland to Pittsburg, 127 miles, amounting to 4s. 4½d. per ton. By the new railway it is expected to be about 2s. per ton, the total then being (say) 10s. 6d. per ton, delivered at Pittsburg.

#### COKING AND BY-PRODUCTS.

The next subject I desire to refer to is the important one of coking. To this day Abram Darby's plan of coking coal in heaps, introduced by him in 1735, is still carried on at Blaenavon, and employed in the manufacture of cold blast iron. With a view of reducing waste as well as of making coke from different classes of coal, and of improving the quality of the coke, ovens of various forms and descriptions have been devised.

The Continental coke makers have paid considerable attention to making coke from mixtures of free and bituminous coals and of recovering the by-products.

By the recovery of by-products a saving is effected of nearly 2s. per ton. Much greater attention has been paid on the Continent to this process than either here or in the United States.

In Scotland large quantities of ammonia sulphate are obtained from the coal used in blast furnaces, and Dr. Mond has succeeded in recovering this valuable product from coal used in gas producers. Indeed, it is now probable that all coal gasified will soon be made to yield up this and other products before being finally burnt.

Considerably over one half of the coke produced in the United States comes from the celebrated Connellsville region, where coke is the cheapest in the world. This coke has been sold at less than 4s. per ton into trucks at the ovens, and the mean price for the last fifteen years has been a little over 6s. 6d. per ton.

The low price of this coke, coupled with its excellent quality and with the low water freight or railway rates, enables it to be used profitably at works situated enormous distances from the coke ovens; for example, works at Chicago, 528 miles from Connellsville, are able to obtain their coke supply at prices which in some parts of this country would be regarded as very advantageous.

Dealing with the subject of fuel leads me to refer to the utilisation of blast-furnace gas as a motive power, which has recently made considerable progress both in Scotland and in Belgium.

Our Vice-President, Mr. James Riley, who is to the front where new improvements are concerned, has recently succeeded in applying blast-furnace gas as a motive power, and through the kindness of Mr. Greiner of the Société Cockerill, I have had the opportunity of seeing an engine that has been working with blast-furnace gas for more than a year, and with such satisfactory results that they have decided to put down immediately two new engines of 150 horse-power each. Indeed, incredible as it may appear, if it were practicable to apply all the gas made at the blast furnaces at Cockerill's for raising power, they would be able to do away with all their boilers except those of the locomotives. These furnaces are worked with coke, not coal.

If blast-furnace gas can be economically applied as the

motive power for driving large engines and for generating electric power, it would almost appear as if pig-iron will soon become a by-product, and the chief work of the ironmaster of the future will be giving light and power to the country.

#### DESULPHURISING.

Now that the problem of dephosphorising has been so satisfactorily solved, there still remains another great difficulty in connection with the manufacture of steel from pig iron of low quality. I refer to desulphurisation.

Saniter and others have been working with considerable success in this direction, but except for special purposes the processes hitherto employed are not largely used. At present, the cheapest and simplest plan is by using the Mixer, by means of which large quantities of molten pig are treated in a large receiver with additions of manganese. By adding 1½ per cent. of manganese to the iron in the mixer the sulphur is very considerably reduced.

Mixing molten iron in large quantities of 100 to 150 tons gives a material of far more regular quality than can be obtained by mixing the iron from two or three blast furnaces in a 10-ton ladle. Moreover, the proportion of wasters in the mills is thereby very considerably reduced.

#### HYDRAULIC FORGING.

In the construction of machines for dealing with iron and steel, great progress has been made ; and in the hydraulic forging press, iron and steel makers and the users of these materials have a useful machine, quick in action, noiseless and exact in work. The press treats the material to be forged, especially steel, in the best possible way, the mass even to the centre being worked and kneaded by it.

Recently at Dowlais we had a very disagreeable reminder of what the interior condition of large masses of iron may be. The shaft of one of the drums at the Bedlinog Colliery, having a length of 27 feet between the bearings and 1 foot 9 inches in diameter, broke after working eighteen years. On examination the interior showed that the scrap iron from which it had been built up had

practically never been welded in the centre—whether it was due to its not having been properly heated, or to, perhaps, too light a hammer having been used in its forging, cannot be determined; but the portions of the fracture showed that the iron forming the interior of the mass had never been either properly worked or welded.

The advantage the hydraulic press possesses is that large masses of steel can be forged which would be impossible to treat with the hammer without the effect of the blows disturbing the whole neighbourhood in which it was working, whereas the strokes by a 5000 or even 10,000 ton hydraulic forging press cause less disturbance than a hammer of a few tons.

One of the largest presses, having regard to the width between the columns as well as to the pressure exerted, was erected by Tannett, Walker & Co. at John Brown & Co.'s works at Sheffield nearly twelve years ago. This press, of 5000 tons with a distance of 18 feet from centre to centre of the columns, affords great facility for handling large pieces.

I recently saw at the works of Krupp at Essen two similar presses, one of 5000 tons and one of 2000 tons. Ingots of high-class steel, weighing 70 tons, were treated by them with the greatest ease, very little labour being involved. Two sets of pumping engines, each capable of giving about 1000 horse-power, are used for actuating them, and so arranged as to be worked either separately or together. There are besides, low pressure pumps for filling and working the various hydraulic labour-saving apparatus in and about the presses.

The experience we now have of the working of these hydraulic presses raises the question whether they could not be usefully employed in the place of cogging mills for cogging slabs for plates as well as for other blooms and forgings.

It is only after witnessing the ease and rapidity with which large masses are treated under the press that its benefits can be fairly appreciated.

#### TIN PLATES.

The tinplate industry employs so large a number of people and consumes such considerable quantities of iron and steel in South Wales that during periods of dearth of work, which have unfortu-

nately been experienced by most of the iron and steel works of this country of late years, the supply of tinplate bars afforded occupation, if not profit, to a considerable number of works.

The tinplate trade of this country is practically confined to South Wales and Staffordshire.

The quantities of plates exported were as follows :

Year.	Tons.	Year.	Tons.
1883	269,375	1890	421,797
1884	288,614	1891	448,379
1885	298,886	1892	395,449
1886	384,692	1893	379,172
1887	353,506	1894	363,928
1888	391,361	1895	366,120
1889	430,650	1896	266,955

Recently this industry, especially in South Wales, has suffered from American competition, and has thus practically lost its best market, but the ever increasing demand for tinplates by other countries will, it is hoped, restore it to something approaching its former prosperity.

The number of mills in the South Wales district is 490, of which about one-third to-day are idle. Tin plates furnish a material which is perhaps the cheapest, cleanest, at the same time the toughest and lightest material for packing purposes that exists. Almost acid proof, entirely waterproof and air-tight, and when worked into certain forms exceedingly stiff and strong, they cannot be replaced by any known material better adapted for the special purposes for which they are used.

#### USES OF STEEL.

New outlets and new uses for the enormous amount of steel the world is producing are being anxiously sought for, but little progress appears to have been made in this country compared with what is being done in the United States, where new uses are being found by its employment in the construction of large buildings. In Chicago, the steel skeleton of one of these gigantic buildings, thirteen storeys high, was erected in twenty-five days, and the entire building, after the foundations were put in, was erected and ready for occupancy in 1897.—i.

less than six and a half months. Still more striking illustrations are afforded by the hotel built for Mr. John Jacob Astor, in New York. It has sixteen storeys, and all the main structural work is of steel, of which the building will contain 10,000 tons. Another of these huge buildings, the Park Row building for office purposes, has thirty storeys! The total amount of steel used will be 9000 tons, or as much as would be required to lay 100 miles of railway with 50-lb. rails.

In collieries the substitution of steel girders for pit-wood and the large and increasing use of steel for building railway waggons and carriages appears to afford a promising outlet for large quantities of material.

#### WAGES AND LABOUR COST.

In various papers that have recently been written on the subject of competition between one country and another, there is not always that distinction drawn that there should be between the rates of wages and labour cost. Rates of wages may be high and labour cost on the finished material low, and wages may be low and the labour cost per unit of finished material high. As a rule wages are high where large outlay has been incurred for the purpose of diminishing the number employed, whilst they are frequently low in older districts where the fact that capital has not been expended has kept back such improvements. In the steel trade what has tended more than anything else to cheapen the labour cost is the introduction of appliances by which large and heavy masses of material, which would be impossible to handle by manual labour, can be dealt with. As a case in point, to make an iron plate of 15 or 16 cwt. from slabs in the old-fashioned way would make heavy demands on manual labour, whereas a steel plate weighing 5 or 6 tons can now, with proper appliances, be made with ease.

#### RAILWAY RATES.

Perhaps, owing to the continent of Europe being divided into so many nations, we are accustomed to speak of European countries as being distant from each other when really compared with the

distances traversed in the United States they are close neighbours. Of late years we have imported and are importing large quantities of iron ore from Spain and from the Mediterranean coast. This ore is carried by sea almost the whole distance, and for certain special manganese ores we have gone as far as the Caucasus, India, Brazil, and even Chili. Even such distances as these are, however, not considered in the United States very excessive, if materials can be carried by water or even by rail, owing to the very low rates charged by their railways, compared with those in Germany, in Belgium, and especially in this country.

No doubt the main element that enables the American iron trade to achieve the wonderful results with regard to the competition with the European continent is the remarkably cheap transport by rail as well as by water, combined with natural advantages. American ore traffic is now being carried over some railways at one-sixth of a penny per ton per mile, and coal at even the lower rate of 0·14 of a penny per mile.

Possibly the lowering of prices of raw materials is due as much to the attention paid to the cost of handling transport as to cheap coke and ore.

If this country could obtain the same low rates of freight on railways that are current in America or even in Belgium and Germany, there is no country where materials for iron and steel making could be more cheaply assembled than in Great Britain. This question is of vital importance to this country. Whether our railway companies will, by adopting low rates for minerals and heavy goods, to some extent approach the rate of one-sixth of a penny per ton per mile and so enable us to retain our hold on the markets of the world, must sooner or later become an Imperial question. If our large population cannot find remunerative employment both it and capital will be driven to other countries.

Europe has already experienced the effect of the competition of the United States in Japan and China, and one cannot help feeling that the ideas previously entertained on the subject of American competition may soon be modified.

The 177,000 miles of railway now operated in the United States are, like the 21,000 miles of railway in the United Kingdom, almost exclusively owned and managed as private

undertakings ; and it may be safely assumed that the exceedingly low rates of freight at present charged in the States on the principal railways, to which I have already drawn attention, have been adopted only after full consideration of the prospects of their proving remunerative, irrespective of their effect in developing the vast mineral resources of that highly favoured country which, as in the case of our own, have proved to be the chief source of its wealth and commercial prosperity.

The table on page 37, kindly furnished me by Mr. Price-Williams, shows the cost of working mineral traffic on some of the principal British railways.

In a recent paper on this subject by that gentleman he has shown that on the London and North-Western Railway, which, with the exception of the North-Eastern, has the largest mineral tonnage of any railway in the United Kingdom, the present average cost per ton per mile for mineral traffic is just one-fifth of a penny. It is obvious that, as this is the average cost throughout the system, the cost of the long-lead traffic must necessarily be much less. Having regard to this fact and to the various economies which have already been effected in the United States by labour-saving appliances in handling the traffic in large quantities, it is evident that the cost of working mineral traffic with increased train loads would be so largely reduced in the future as to admit of an approximation of the English mineral rates of freight to those of the United States.

In fact it is not too much to say that unless large reductions are made in the existing rates it will be impossible for the iron and steel manufacturers in this country to continue to reap the benefit of the great natural advantages its insular and central position give it, and of retaining the paramount position it has acquired as the great commercial centre of the world.

In addition there is to be considered the keen competition of other countries. The principal railways of the Continent are owned by the State, whose primary object is, and should be, to utilise them as far as possible for the purpose of developing the resources of their respective countries. The great reductions that have been made in the rates for this purpose practically amount to a bounty on the iron and steel industries, securing for them a most favourable position in the markets of the world.

RECEIPTS AND WORKING EXPENSES AND NET RECEIPTS, 1895.  
(250 tons net load.)

	Receipts.			Working Expenses.			Net Receipts.			Tons.
	Per train mile.	Per full train mile.	Per ton per mile.	Per full train mile.	Per ton per mile.	Per train mile.	Per full train mile.	Per ton per mile.	Per full train mile.	
Great Western .	58·64	106·44	d.	0·4257	28·61	d.	0·2078	80·08	d.	22,567,000
Great Northern .	40·80	74·18	0·2967	22·96	41·74	0·1669	17·84	32·44	0·1298	7,164,000
North British .	60·82	110·58	0·4423	28·68	52·15	0·2086	32·14	58·48	0·2857	13,961,000
Taff Vale .	78·87	143·40	0·4100	40·98	73·42	0·2090	38·49	69·98	0·2010	13,015,000
L. & N. W. .	57·89	105·26	0·4210	35·44	64·44	0·2578	22·45	40·82	0·1632	28,889,000
North-Eastern .	76·54	139·16	0·5567	44·98	81·78	0·3271	31·56	57·98	0·2295	38,937,909

The difference of cost between long and short haulage is fully recognised by freighters, but the railway companies in this country have not increased the capacity of waggons, and by so doing reduced their tare, as much as they have done in other countries. When the Taff Vale Railway Company first commenced to carry coal the waggons were built to carry 5-ton loads, which were afterwards increased to 6, then to 7, then to 8, and now to 10 tons, and the railways and the docks of South Wales could not possibly do anything approaching the quantity of traffic they are called upon to deal with to-day had the coal trucks retained their very small capacity. After having had considerable pressure brought to bear upon them, some of the railway companies have allowed 12- and 15-ton trucks to run on their systems, much to the advantage of themselves and freighters. If, however, instead of 15-ton trucks 25-ton or even 40-ton trucks were used for carrying minerals and heavy goods, the advantage derived from the increased facilities in handling these materials would have considerable influence in reducing the costs. A striking illustration of the economies which have resulted from largely increasing the carrying capacity of the waggons and the consequent reduction in the tare weight has occurred in New South Wales, where Mr. Eddy, the Chief Commissioner of Railways, has in this way been able to dispense with bank engines on the many severe grade lines in that colony, and largely to increase the train loads, with the result that during an unparalleled period of commercial depression these State-owned railways, which had previously been a burden to the country, now largely contribute to its revenue.

As a further illustration of the large saving in cost which has been effected in this way, it may be mentioned that in 1896 the entire freight traffic receipts on the New York Central Railway, half of which consists of coal, iron ore, and other heavy goods, has been reduced to just one third of a penny per ton per mile.

To sum up the whole matter, it is beyond question that it will be through the agency of the large reductions already effected and constantly being effected in the cost of manufacture, to which I have drawn attention, combined with adequate and commensurate reductions in the cost of transport of the raw and finished materials, that the iron and steel industries of this

country will be able to maintain their hold on the markets of the world. The iron and steel manufacturers have done and are still doing all in their power to reduce the cost of manufacture, and it remains for the great railway companies in this country, who are obviously deeply interested in the maintenance and development of the chief sources of their traffic, to supplement these efforts by large reductions in the cost of transport and of dealing with the large and heavy masses of material that the altered condition of trade demands.

#### LABOUR QUESTIONS.

My predecessor, Sir David Dale, in his able address, referred to the increasing difficulties and hindrance to the steady conduct of our trade by labour difficulties. There is certainly no question at present that occupies or deserves to occupy more serious consideration of both employers and employed than that of avoiding strikes and disputes. In my own district, owing largely to the guidance of its originator, Sir William Lewis, a sliding scale arrangement has existed in the coal trade of South Wales for more than twenty-one years, now controlling the wages of upwards of 100,000 workmen, but successful as it has been, and much as it has done for the district, we have had times of serious trouble and anxiety. If the two parties most interested are unable or unwilling to settle their disputes I have little faith in the matter being referred to a third party who may or may not know, and frequently cannot know, all the circumstances of the case; but any method of conciliation which will replace the barbarous methods of brute force must have the warmest support of all thinking men.

Probably no single factor tends to unsettle business so much as the strikes and lock-outs which, from time to time, occur all over the world, and perhaps more frequently in our country than in others. Wherever they occur the loss to both sides is enormous. In some instances not only are large sums of money lost, but also profitable markets that can never be recovered, and whether employer or employed are the victors the workmen lose the savings of years, and not infrequently their steady

habits, while the employers lose both their money and customers, to the detriment of themselves and of those they employ.

Sir David Dale concluded his powerful address to this Institute by saying that, "Neither capital nor labour can afford to do anything which tends to hamper that cordial co-operation by which alone the well-being of the community can be secured."

In this view I heartily concur, and can only add that whoever discovers a means by which disputes between employers and employed can be fairly and honestly settled will deserve well of his country and of the world at large.\*

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Mr. WINDSOR RICHARDS, Past-President, said that in these days of numerous scientific societies and addresses, the difficulty of selecting subjects which were generally interesting became a more and more onerous task. All would agree that the President had succeeded in finding interesting topics, and had dealt with them in a very able and practical manner, and that he had given an address which was highly instructive and useful to the members of the Institute, and indeed to every one connected with metallurgical operations. Presidential addresses, necessarily short, and embracing a great variety of subjects, could only, as it were, touch the fringes of them, and discussions were quite undesirable. He would offer to the new President, on behalf of the members of the Institute and on his own behalf, their most hearty congratulations on his having attained the high and honourable position of President of the Institute. He would congratulate members also on their having secured the services of a conscientious and honourable man, who would give his best attention to the highest interests of the Institute. In conclusion, he proposed with much pleasure that the most hearty thanks of the Iron and Steel Institute be presented to the President, Mr. Edward Pritchard Martin, for his admirable and instructive address, and that he be requested to allow it to be printed in the Proceedings of the Institute.

\* Since this address was delivered I regret to find that, in connection with the subject of hydraulic forging, I omitted to refer to the epoch-making work of Armstrong in the general application of hydraulic power, and of Whitworth in compressing steel.—E. P. M.

Sir LOWTHIAN BELL, Bart., Past-President, said he quite agreed with the sentiments enunciated by the previous speaker. It was indeed a very difficult thing for an in-coming President to select a subject of sufficient interest to be grateful to those who had to listen to it; but there was a still greater difficulty, and that was the difficulty of finding a gentleman who would be able to deal with the subject, having found it, so competently as their chief officer had done. It had been his privilege to know Mr. Martin for very many years, and he would confess that he would have great difficulty in finding any one as capable, and certainly none more capable, of doing justice to the subject than he had shown himself to be. Mr. Martin, as all knew, was a most competent judge of the relative facilities possessed by different districts of the world, and, in addition, he possessed the valuable quality of being able to approach a question without any attempt at sentiment or exaggeration. He had very great pleasure in seconding the proposed vote of thanks.

The resolution was put to the meeting, and carried with applause.

The PRESIDENT, in returning thanks, said that he would again assure them that no efforts on his part would be wanting to make his term of office a success.

The following paper was then submitted :—

## MICROSCOPE ACCESSORIES FOR METALLOGRAPHERS.

BY JOHN E. STEAD, F.I.C., MEMBER OF COUNCIL.

As it is evident that the science of the microscopic study of metals, introduced by Dr. Sorby thirty years ago, is rapidly becoming popular and of practical value, and it being known that it can only be after a long and close individual study that the student can be able to understand and interpret the significance of what the microscope reveals, it is thought that any hint which will facilitate and enable the metal-microscopist to get through his work rapidly will not be unwelcome.

During the last few years I have diligently prosecuted metal-micrographic work, or, as it might be termed, the study of "Metallography."\* During such studies it has been necessary to cut and prepare hundreds of sections of metals and their alloys, and as this cutting and preparation at first occupied a very large amount of time, endeavours were naturally made to find means whereby the physical labour and time might be materially shortened. At first all specimens which were capable of being hand-cut were hand-sawn by the excellent little blades manufactured by the Millar's Fall Manufacturing Co., but soon after it was found that this same company manufactured special machines which could be driven by power or be worked by hand, and as these machines are admirably adapted for the metal-microscopist, a sketch and a brief description is here introduced (Fig. 1).

It will be noticed that the sample is held in a horizontal vice, and it is capable of taking pieces  $3\frac{1}{2}$  by 5 inches in section. An 80-lb. steel rail can be readily held in this machine and be cut

\* The term metallography is not one usually employed in metallurgy, and might, we think, be used instead of the more lengthy term given to it by Mr. F. Osmond of "micro-metallography."

into sections. The saw frame is caused to travel backwards and forwards about forty times per minute, and is kept in a true line by a guide, upon which the frame slides. The pressure on the work can be regulated by weights which may be placed on the top of the guide carrying the frame. It only requires about a boy-power to work it, and this can be applied either by a boy himself or an equivalent power from an available engine shaft, or by either a small gas or steam engine or electric motor. As soon as the piece is cut, by a very ingenious arrangement a small clutch is thrown out, and the saw at once ceases to travel, and if

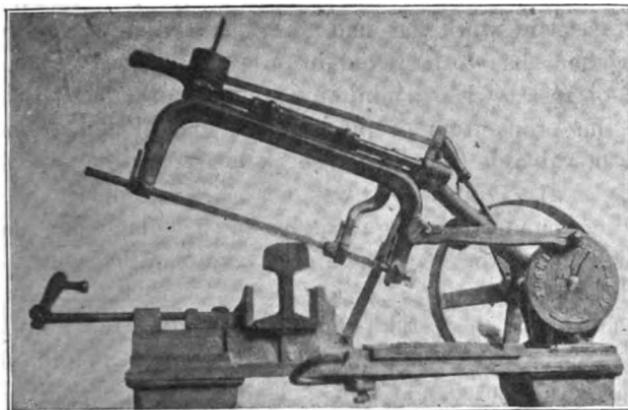


FIG. 1.—Mechanical Saw.

necessary an arrangement can be adapted so that when the work is done an electric bell is made to ring in any part of the building, calling the attention of the attendant. When large sections are to be made, the time taken may exceed two hours, and in such a case it is not necessary to superintend the operation, as the machine will work well without attention, and it is important to have some means to indicate when the work is completed, hence the importance of having a bell. It is possible to cut out pieces little more than one-hundredth of an inch in thickness if desired.

The pieces when cut are polished up by a method practically identical with that described by Dr. Sorby.

#### MOUNTING THE SPECIMENS.

It often happens that the pieces of steel or metal to be polished, either because of their extreme hardness or other cause, are not regular in shape, and the surfaces polished are not parallel with the opposite sides. I believe that nearly all other workers cut or grind the pieces until the two sides are parallel, and when they have abundance of time and plenty of assistance it is a very desirable condition of things to obtain; but in my own case the work has had to be done in leisure hours, and every moment has to be saved in order to arrive at a maximum amount of result with a minimum amount of labour and time, and as the preparation of pieces of regular thickness involved the loss of valuable time, and also as it is only one flat surface which is really required, it was necessary to devise a simple method of mounting irregular shapes on glass so that the polished face of the sections are always parallel with that of the microscope slide.

The apparatus may take many forms, but in that I have adopted it consists of an arrangement similar to a simple microtome for section cutting.

A still more simple device consists of a piece of plate-glass on which are cemented at opposite sides strips of glass of equal thickness. There are four sets or steps having a depth or thickness of  $\frac{1}{8}$  in., the second  $\frac{3}{16}$  in., the third  $\frac{1}{4}$  in., the fourth  $\frac{5}{16}$  in. This arrangement can be made by any one, and costs practically nothing.

The following sketches explain sufficiently the character of these simple apparatus, and they also indicate how they are to be used.

#### PLASTIC BEDDING MATERIAL.

In examining metal sections, it is necessary to make many observations on the same piece. First, after simply polishing; second, after polishing and attacking with liquorice infusion,

called by Mr. Osmond, the " Polish Attack "; third, after slightly etching with iodine or other corrosive solvents, and several times after, when the section is still more and more acted upon by such solvents. This being the case, it is important that a simple means should be adopted to rapidly and perfectly level and attach them to the slides temporarily, without having to resort to the use of Canada balsam, or other similar adhesives. I have found that by the use of very simple apparatus it may be rapidly effected.

The temporary support is a plastic material made by mixing thick petroleum oil with common whiting, and it is applied in



FIG. 2.—Levelling and Mounting Stand with Screw.

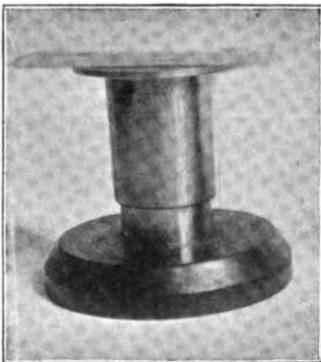


FIG. 3.—Levelling and Mounting Stand with Slide.

the following manner: The irregularly-shaped mass or section of metal is placed polished face downward upon the head of the microtome, or upon the plate-glass of the second and more simple apparatus, and at such a distance from the levels that a slide placed across them will barely touch the back of the specimen. A piece of the plastic material above referred to is then pressed upon the centre of the slide to which it adheres; this is then turned down, and is pressed on to the back of the specimen until the glass rests on the guides on each side; the slide is then removed with the section adhering to it, having its polished surface exactly parallel with that of the slide. The whole operation

only takes about three seconds to complete. After examination, the section may be removed most readily, and further treated if necessary. When it is necessary to rigidly mount the section, it is placed in the same position on the levelling stage, but is slightly warmed previously, as also is the slide. A sufficient quantity of a mixture of beeswax and rosin, 1 to 1, is dropped upon the centre of the slide, and this is then turned over, and is placed on the section so that the cement comes in contact with the metal. It is allowed to cool in this position, and when cold is ready for covering.

Canada balsam is a good material for mounting most metals. In many cases the colour of iron specimens changes in time; but it has been found that if steel or iron specimens have been well soaked in lime-water, and, after having been washed with water and

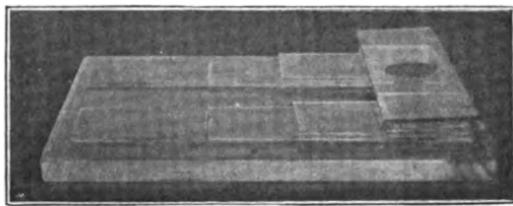


FIG. 4.—Levelling and Mounting Stand with Fixed Steps.

alcohol, then heated to about 150° C. for a short time previous to being covered, the colour does not change, at least in a trial of one year. Whether or not it will change in a longer period, time alone will tell. The balsam should be very thick, and be applied after heating to the heated specimen. A temperature of 100° C. is sufficient. Every book on the microscope fully explains how to fix the cover glass with Canada balsam; such instructions need not therefore be repeated here.

All examinations and photographs are best made on the uncovered specimens, for the reflection from the glass of covered objects, when vertical light is employed, causes a flare of light which makes it difficult to see clearly the finer details, and almost impossible to photograph them.

## SIMPLE METHOD OF ILLUMINATION.

In the examination of metals and alloys it frequently happens that a low-power objective is necessary, and in such cases it is important to have large areas of the specimen very perfectly illuminated with vertical light. The method I have adopted answers the purpose admirably, and is constructed out of a microscope slide 1 inch by 3 inches and a very thin cover glass, the size varying according to the objective in use. A stick of sealing-wax 1 inch long and a quarter-inch square, more or less according to requirements, is melted upon and across the surface of the cover glass about 1 inch from one end. After this has set, the edge of the cover glass is gently heated, and is embedded whilst still hot along the edge of the sealing-wax, at an angle of  $45^{\circ}$ , where it is retained in position until it is fixed. A piece of card 1 inch square is thoroughly well smoked by holding it over a burning taper until the soot completely covers the surface. It is then, whilst still hot, placed vertically into the sealing-wax immediately behind the glass reflector. This is to prevent light from the microscope stand or from the room being reflected into the microscope.

This arrangement is very satisfactory, and half-a-dozen such illuminators may be used for as many different object-glasses.

The following sketch will make the matter thoroughly clear :—

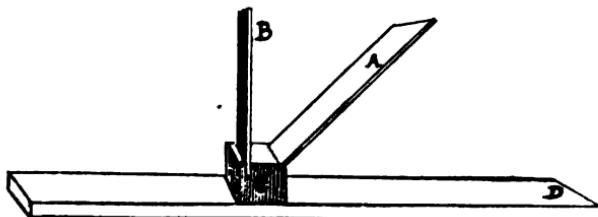


FIG. 5.—Simple Illuminator.

A, Cover-glass reflector; B, Cover-glass smoked; C, Sealing-wax;  
D, Microscope slide.

## THE UNIVERSAL ILLUMINATOR FOR LOW POWERS.

This arrangement I have designed so that the glass reflector can be turned to any angle, and can be raised or lowered as

may be desired according to the thickness of the specimen examined, and when not in use can be packed up into very small compass.

The following sketch will explain its form :—

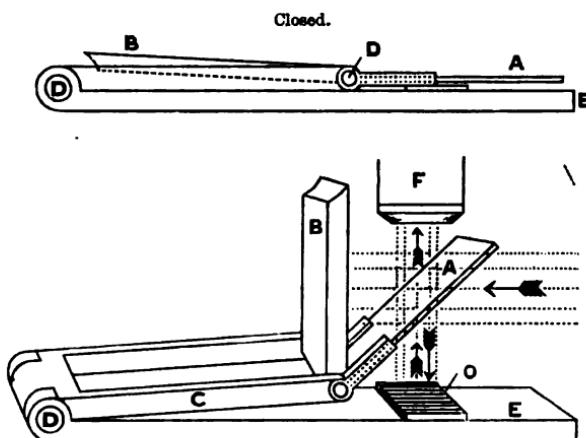


FIG. 6.—Universal Illuminator.

*A* is a thin cover-glass from  $\frac{1}{4}$ -inch to  $1\frac{1}{2}$ -inch square as required ; *B* is a blackened screen ; *C* is an adjustable frame hinged at *D*, and attached to the base *E*, which is placed when in use on the microscope stage ; *F* represents the object-glass of the microscope.

The dotted lines represent the rays of light. Such rays as pass right through the reflector and impinge on *B* are there absorbed and eliminated. Those which are reflected downwards at an angle of  $45^\circ$  fall on the object *O*, and then return upwards into the object-glass above. The arrows clearly show the direction which the useful rays take.

#### MICRO-MECHANICAL APPARATUS.

It is often desirable, after the examination of a metal, to determine what part of the structure is weakest, and this it is found can often be done by bending the microscopic section itself, either by steadily-applied pressure, or by percussive force, taking care of course to arrange to have the polished surface convex. This can be readily effected by placing the section, polished side down, over a V space cut out of a solid piece of steel, and applying force to the back so as to bend the specimen.

As this method of investigation was found to be most useful, a

simple form of apparatus was devised to facilitate the work, the nature of which will be readily understood by help of the following diagram:—

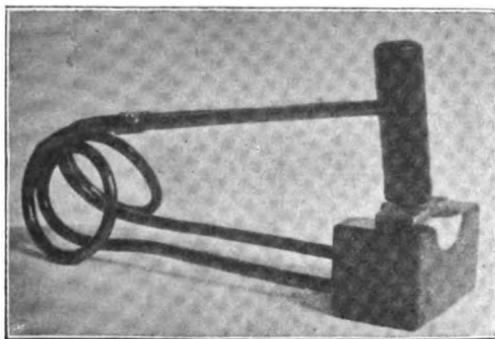


FIG. 7.—Micro-Mechanical Apparatus.

The spring attached to the block carries at the other end a small blunt chisel of steel, which naturally rests with some force on the bottom of the recess in the block. The specimen to be examined is laid across this recess, and the chisel allowed to rest on its back, where, owing to the force of the spring, it is kept in position.

If it is desired that a gentle and steady pressure be applied, the block and chisel are placed between the jaws of a vice, and are then screwed up to the desired pitch.

If percussive force is desired, the chisel is struck with a hammer.

Sometimes a piece breaks, but that does not matter; for the two portions are then placed together again on a glass slide, and are examined, when the track of the fracture can be readily traced, and the nature of the structure through which it has passed noted.

If the piece does not break right through, the weak places often do give way, and it is easy to see under the microscope what the structure is like at these places.

The diagrams illustrate fully the value of this method of investigation.

The first (No. 8) is a piece of wrought-iron which has been  
1897.—i.

D

bent in a line with the grain, or direction of rolling, showing the weakness located where the cinder is present.

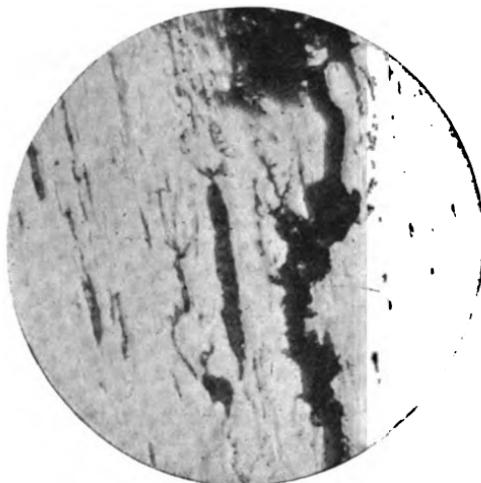


FIG. 8.—Wrought-Iron showing Cinder.



FIG. 9.—Carbide of Iron in Blister Steel.

The second (No. 9) shows that the cementite or carbide of iron in blister-steel is the track along which the fracture travels.

The third (No. 10) is tin containing phosphorus, showing that the weak points are located in the white areas of phosphide of tin.

Many more illustrations might be given of the use of micro-



FIG. 10.—Tin containing Phosphorus.

mechanical examinations of steel, but it is not necessary, as those given are sufficient to demonstrate its value.

#### MICRO-PHOTOGRAPHIC APPARATUS.

It is very often of importance to photograph the structures of metals, and a great many micro-photographs of very high value have been brought before our notice.

Dr. Sorby of course was the pioneer in this work, and later Professor Martens, Messrs. F. Osmond, G. Charpy, and others have produced results of exceptional excellence.

I believe most of these gentlemen have used photographic arrangements which necessitated the microscope tube being turned down in the horizontal position, but this difficulty has been got over by certain gentlemen by a special arrangement, in which the microscope is retained in a vertical position, and the vertical

rays are reflected to the horizontal plate by a suitable mirror placed at right angles inside the tube itself. This arrangement is an excellent one, and undoubtedly gives good results, and where a very long camera body is required, is in my opinion preferable to any other.

For general work, however, I have found that a much more simple arrangement is preferable, and as I have taken more than 600 micro-photographs by it, and know how easy it is worked, I introduce here a brief description.

The following two sketches will practically explain the nature of the apparatus.

It will be observed that the microscope stands between two parallel guides, fixed upon the base of the stand, and these are about 15 inches apart, quite sufficient space for the head of the microscopist to pass between. The camera is of conical bellows form. The back or top is cut out from a flat 1-inch board, with an opening in the centre large enough to take a 7 by 5 plate carrier or "back," and is arranged so as to fit into the openings of the parallel guides, between which it can be readily raised up or down, and can be secured at any point by slightly turning the two sets of screws, one at each side.

The first figure represents the normal position of the microscope, which is always used in a vertical position, the camera being simply secured at the top of the frame, and is quite out of range of the head of the microscopist.

When the photograph has to be taken, the object being in exact visual focus, the camera is lowered until the loose fitting cap falls over the eyepiece. The focussing is now effected by placing a flat piece of clear glass at the top of the camera instead of the ordinary ground glass, and the object is examined through a second eyepiece, which is simply placed upon the glass surface, the final adjustments being made by turning the micrometer screw on the microscope. The sensitive plate is now placed on the top, in a dark slide, and the slide being opened the exposure is given, the plate removed and developed, and the camera raised upwards out of the way. The fixing of the camera and focussing does not take more than a few seconds.

The great advantage in this arrangement is its cheapness, the cost being only about 30s.

My object in writing this paper is to facilitate the work of students in the study of metallography. Probably, before long, many minds will evolve better methods, and I hope that what I have done will assist in that direction.

In conclusion, I must point out that it is only in exceptional cases that the microscope is likely to be of practical value to the

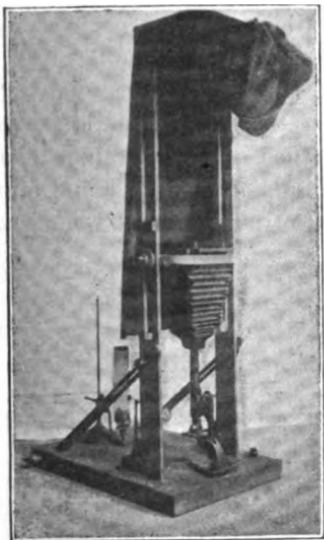


FIG. 11.—Micro-Photographic Apparatus when taking Photograph.

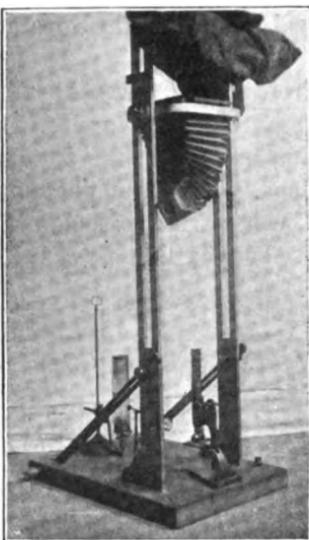


FIG. 12.—Micro-Photographic Apparatus after taking Photograph.

steel-maker, as it is only most rarely he makes steel which breaks or fails mysteriously, upon which he requires more light, and that, in many such cases, it will be found to be most valuable, although it will, I believe, be also a valuable guide in determining the best treatment steel should have in its manufacture.

### DISCUSSION.

Mr. J. E. STEAD, Member of Council, requested that the paper might be taken as read, because it was simply a series of notes to facilitate the work of microscopists. If the paper was not clear enough, he should be happy to answer individually any questions that the members might ask him, and also to show the work that he had done with the apparatus described.

Professor ROBERTS-AUSTEN, C.B., Member of Council, hoped the beautiful photographs exhibited by Mr. Stead would prevent authors employing the antiquated method of *drawing* their micro-sections. Now that photography as applied to metals and alloys had been carried to such a high point of perfection, it was absurd not to employ that process.

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### CORRESPONDENCE.

Mr. F. OSMOND was quite in accord with the author, and thought that his (the author's) hints should be very useful to beginners. Mounting the specimens, he said, on a soft backing and illuminating them by an inclined plate of glass when using low powers, were processes ordinarily adopted in microscopic laboratories in France. The vertical arrangement of the camera as described, and justly recommended by the author, was practically identical with that which he himself had used for eight years, and was devised by the firm of Messrs. Nachet for petrography. The device worked exceedingly well. The only objection that could be taken to it was that the observer must stand on a stool to focus the plate, when the desired enlargement necessitated a somewhat long extension of the bellows. This, however, was not a very serious inconvenience.

Mr. E. H. SANITER thought that all those who, like himself, were struggling forward in metallography with a deficiency of information, must thank the author for adding his useful paper to the scanty literature on that subject.

The method used by him (Mr. Saniter) in permanently mounting specimens differed slightly from the author's. His method was the following:—As soon as the specimen was etched satisfactorily, it was smeared with Canada balsam, and pressed firmly on to the cover-glass, which had previously been placed on a slip of glass. The slip of glass with cover and specimen was then heated for about ten minutes at 100° C., and allowed to cool, when the specimen was found to adhere firmly to the cover. The back of the specimen and cover was then varnished with sealing-wax dissolved in alcohol, which served the double purpose of preventing rusting being started at the back, and also of causing the specimen to adhere firmly to the slide, as described farther on.

The cover and specimen were then placed without heating on the levelling stage, and a heated microscope slip on which had been melted some sealing-wax was placed on the stage, so that the specimen came in contact with the hot sealing-wax; a hot halfpenny was then placed on the slide to cause the sealing-wax to run. This gave a very firm mounting.

Specimens mounted in that way without any other treatment had not deteriorated in any way in twelve months. He had not experienced any difficulty in photographing through the cover-glass when using  $\frac{1}{2}$ -inch and  $\frac{1}{4}$ -inch objectives and Beck's vertical reflector.

The PRESIDENT moved a vote of thanks to Mr. Stead, which was carried by acclamation.

The PRESIDENT said the next paper was by Mr. Henry William Hollis on the "Weardale Furnace." The members, he said, well knew Mr. Hollis, and had not forgotten the reception he had given them in the North of England, when, during the Darlington Meeting, they had been privileged to visit his works.

## THE "WEARDALE" FURNACE.

BY HENRY WILLIAM HOLLIS,

GENERAL MANAGER OF THE WEARDALE IRON AND COAL COMPANY, LIMITED.

IT is somewhat remarkable that amid the numerous improvements made during the last twenty or thirty years, in almost all stages of the conversion of pig iron into the finished product of the rolling mill, one of the most important of the intermediate appliances, viz., the reheating furnace, has undergone, comparatively, little change. In most of the rolling mills of this country the type of furnace used for preparing slabs of steel or piles of iron for the mill remains what may be described as a puddling furnace with a flat bottom instead of a concave bath; that is to say, a heating chamber, generally of oval form on plan, with a fire-grate at its wider end, and a chimney flue, or neck, at the narrower end; the slabs or piles introduced through a door or doors at one side of the chamber being heated by the flame passing over them from the fire-grate to the chimney. Almost the only improvement made in recent years in this primitive form of furnace, has been the closing in of the previously open space under the fire-bars, and the forcing of air into the closed chamber so formed by means of one or more steam jets blowing through tuyeres, thus working the furnace under forced draught. As regards the output of the furnace, this was doubtless a great improvement, but I am not sure that the consumption of fuel was not increased in an equal ratio.

My attention has been for a long time directed to the subject of reheating furnaces, and after innumerable experiments and many failures, I have now perfected the gas furnace about to be described, which, for simplicity of construction, low first cost, absence of expenditure in repairs, and ease and economy of working, unites advantages not, as I believe, previously attained.

In the foregoing remarks, I do not ignore the regenerative furnace, either in its original form or the more recent design wherein the regenerating chambers are for the air alone, the gas-producers being a structural part of the furnace itself. This

form of furnace, admirable as it is in many respects, has not been generally adopted to the exclusion of its ancient rival.

Before describing in detail the construction of my new furnace, it may not be uninteresting to refer briefly to the experimental trials from which it has been elaborated, premising that my object has been to dispense with regenerating chambers altogether, on account of their cost; to obtain continuous working without reversing the course of the flame; and also to get rid of the disadvantages attendant upon frequent stoppages for clearing or renewal of brick checker-work. I also had in view the introduction of the flame in such a way as to obtain equal heating over the whole floor of the furnace chamber. There were other minor considerations influencing my design, but I need not make special reference to them.

The broad principle upon which my furnace is constructed is the introduction of a gas flame through, and surrounded by, a stratum of highly heated air in the roof of the furnace, the flame pouring down upon the slabs or piles to be heated, and passing along the floor of the working chamber to an outlet port at each end.

I was led to adopt this principle by the recollection of an experiment made many years ago with a blast-heating pipe stove of a blast-furnace. The waste gases from the furnace were led into the summit of the stove, the flame passing between the cast iron elliptical blast-pipes and out at the bottom of the stove. The result was that the pipes were almost immediately melted, and the stove practically destroyed.

My first trial was with a model or miniature furnace, 4 feet by 3 feet, with the gas introduced through a single 3-inch pipe in the centre of the roof arch, cold air being admitted through four holes in the arch close to the gas inlet, the flame passing through three outlet ports at each end into an external flue leading to an iron pipe serving as a chimney. The interior of the little furnace was speedily brought to a bright red heat, and this, it must be borne in mind, without any heating of the air which supported the combustion of the gas. I next added a rudely constructed outer roof, and passed the air into the furnace through a rudimentary hot chamber between the two roofs; by this a considerable increase of temperature was obtained, and I felt myself to be on the right track. My next experiment, in November 1895, although still on a small scale compared with

subsequent efforts, was somewhat more ambitious than the little dog-kennel just described. It was a furnace 7 feet square, the roof being formed with two 9-inch concentric arches having a 9-inch space between them. The back wall was made double, and the air of combustion was introduced across the ends of the furnace into the space between the two walls, and thence into the space between the two roof arches, through twelve square tubes of fireclay, six in each end of the furnace, which tubes were maintained at a red heat by the outgoing flame passing between and around them. The gas was introduced through a 9-inch fireclay tube set solid in the upper arch, and passing centrally through a circular port in the lower arch large enough to allow a 2-inch annular space all round the gas inlet tube, through which space the hot air was admitted into the furnace. I had now arrived at an arrangement theoretically good, but—as is often the case—practically useless, as will be hereafter seen. Nevertheless, in this furnace cold steel slabs were brought to a rolling heat in about an hour or little more, and 1200 green fire-bricks were perfectly burned in much less time than that required at the kilns in the ordinary process of manufacture. My next experiment was to try the furnace in the melting of pig iron; the time required for the melting of a ton of pigs to the state of fluidity required in foundry work being afterwards used as the measure of comparative success attained by structural alterations in the furnace itself. The trials were as follows:—

**Experiment.**

No. 1. Furnace as described . . . . .	2 hrs. 0 mins.
„ 2. Air driven in by steam jet blowers; evidently in too great volume to admit of its being sufficiently heated . . . . .	2 hrs. 42 mins.
„ 3. Single tube gas inlet altered into burner with four cast-iron tubes, with the intention of securing a more intimate admixture of gas and air, the air being admitted to the furnace through a flue at each end built of fire-brick quoins along the outside of which the flame passed; the twelve fireclay tubes previously used having all split and become useless in a few days . . . . .	1 hr. 20 mins.
„ 4. Burner with nine tubes, eight in a circle surrounding one in centre . . . . .	1 hr. 20 mins.

**Experiment.**

- No. 5. Furnace in its present form without tubes,  
gas being admitted through a circular port  
in upper arch centrally over a larger port  
in lower arch . . . . . 1 hr. 0 mins.
- „ 6. The built-up air flues changed for large elliptical tubes of fireclay two inches thick,  
one at each end of furnace : these tubes  
quickly split and fell to pieces . . . . . 1 hr. 0 mins.

My next proceeding, during the time when these experiments were in progress, was the erection at our "No. 3" plate-mill of the furnace represented in Figs. 1, 2, 3, 4, 5, and 6.

- Fig. 1. Plan on level of heating-chamber floor.  
 „ 2. Half front elevation ; half longitudinal section.  
 „ 3. Central cross section.  
 „ 4. End cross section.  
 „ 5. End elevation.  
 „ 6. Roof plan.

The same reference letters indicate the same parts in all the Figs.

- A Heating chamber.
- B Hot-air space between back walls.
- C Fireclay air-heating tubes.
- D Flame outlet ports.
- E Air inlets.
- F Doorways.
- G Doors.
- H Buckstays.
- I Air slides.
- J Slag outlets.
- K Gas box.
- L Hand-wheel for lifting gas valve.
- M Hot air space between roof arches.
- N Chimneys.
- O Foreplates of doors.
- P Lower roof arch.
- Q Upper roof arch.
- R Gas valve.
- S Gas inlet tube.
- T Annular air inlet port.
- U Brick stopping of arch giving access to flame chamber.
- V Tie rods.
- W Lever lifting gas valve.

This furnace, in its primary form, was of construction similar to the experimental one already described, and had a heating chamber 12 feet by 7 feet. It worked fairly well in heating steel slabs for the mill, but was too short to obtain the full efficiency of the gas flame. By its use, and by the experiments in melting pig iron at the smaller furnace, I had now ascertained two facts. First, that no advantage was gained by breaking up the inflowing current of gas by any tubular arrangement of burner, but that far greater heat was obtained by commencing the combustion above the inner arch, and in the presence of an inflowing current of highly heated air entirely surrounding the descending column of gas. I may here remark that I did not obtain perfect combustion of the gas before it reached the floor of the furnace chamber until I had discarded the plan of introducing the gas through tubes; this was proved by the disappearance of a deposit of carbon where the flame first impinged upon the floor, which was found in all the earlier experiments. My second conviction was that any attempt to introduce and heat the air by passing it through red-hot tubes of fireclay was useless, the difference in temperature of the inside and outside of such tubes causing their rapid destruction. I scarcely like to confess that one of my failures was a trial for this purpose of cast iron elliptical tubes such as were formerly used in the stoves of our blast-furnaces; these melted completely away before the furnace came to its full heat.

It will be observed in Fig. 1 that at each end of the furnace five outlet ports are shown; these were reduced to three, then to two, and finally to one, which is situated as near as possible to the front of the furnace, in order to counteract the cooling effect of the air drawn in round the doors. If we can effectively heat the front of the furnace, radiation will take care of the back.

I have referred at so great length to these experiments—which occupied about twelve months—in order that by so doing I may anticipate suggestions for improvements which have already been tried and abandoned, and that I may give to others the benefit of my failures as well as of my successes.

I next lengthened the furnace chamber to 20 feet by 7 feet, adding two more doors, and altering the gas and air inlet arrangements to the system hereafter described, in which we have finally

rested, the external appearance of the furnace becoming as represented by Figs. 7 and 8. Fig. 7 shows the front or working side of the furnace. Fig. 8 shows the position of the two small gas-producers at the back, from which the gas is introduced into the furnace through three 9-inch circular ports in the middle third of the centre line of the upper roof arch. A single slag outlet in the centre of the back wall has taken the place of the two outlets shown at the ends of the furnace. The mill is a small pull-over one, previously worked with four coal-fired furnaces, and then having an output of about 23 tons of plates per shift. The new furnace now took the place of the four coal-fired furnaces and did the whole work of the mill, indeed increasing the output to about 27 tons per shift, and supplying the slabs with such prompt regularity that the output was limited by the capacity of the mill, and not by the power of the furnace. Forty tons of slabs 3 inches thick have been heated by this furnace in one shift. It must be observed that this mill is a small one, and that with such slabs as were used, viz., from 400 to 1000 lbs. weight, the work done by the furnace is not to be taken as representing what it could have accomplished with larger slabs. The consumption of fuel was reduced about  $4\frac{1}{2}$  cwts. per ton of sheared plates, and the waste in weight of slabs heated was reduced 1 per cent., as compared with the fuel and waste in the coal-fired furnaces. The cost of repairs has been merely nominal, the saving in this item having been about £3, 15s. per week. Altogether, the economy effected by the new mode of heating represented, with the mill giving an output of 27 tons per shift, a little over £30 per week, or 2s. 3d. per ton of finished plates. The plates came from the rolls with a clean and perfect surface, and a remark made to me by one of the men at the mill was, "The slabs roll so much hotter than they look as if they would." A very valuable advantage in the new furnace was found to be that when the slabs had attained rolling heat, they could be kept at that temperature, if required, for several hours, without any danger of the well-known "burning," by simply closing the air slides; this is extremely useful in the event of any interruption in the regular running of the mill. Cold slabs of 1100 lbs. weight have been rolled from this furnace in forty-two minutes from time of charging.

The old method of working consisted of putting into a coal-

fired furnace as many slabs as it would hold, and then waiting until they were ready for the mill, upon which they were rolled, one by one, until the furnace was empty, when the sand bottom had generally to be repaired, and the process was then repeated for another "heat," as it was termed. In the new furnace the working is continuous, charging going on at one door at the same time as slabs are being withdrawn at another, and the furnace is never empty. I had some difficulty in inducing the furnacemen to adopt the continuous charging, and I remember saying to them, "I want you to give up the system of completely emptying the furnace, and then filling it with slabs from end to end, and sitting down and smoking your pipes and talking politics until the slabs all come ready at once. I want you to charge two fresh slabs for every two you draw." After the new method of working had become established, I was glad to have this remark from one of the furnacemen, "No time for pipes and politics now, sir!"

Although this furnace has done, and is still capable of doing, excellent work, its performance has been far surpassed by that of the two large furnaces erected at our new plate-mills, of which I now proceed to give a description. I have referred to it in such full detail because it was really a successful practical application of the new departure, and because it aptly illustrates such a plant as may be put down where a single furnace of moderate size, with its own gas supply, is required. The greatest economy of fuel will be attained with a furnace adapted to the work it has to do; and it would be a wasteful mode of working to heat slabs of 100 or 200 lbs. weight in a furnace capable of heating slabs of several tons. I may also here remark that two or more furnaces, fed from a common gas supply, will work more uniformly and more economically than single furnaces separately supplied with gas. It is a great advantage to have a battery of producers from which the gas may be led wherever it is required within reasonable distance, on account of the facility with which coal may be brought to, and ashes taken away from, the producers. The distance to which producer-gas may be taken in underground flues, without appreciable loss of its initial heat, is much greater than is generally supposed, and this is an important point, because the conditions of working in this respect are exactly the reverse of those which obtain in the melting furnace,

where the gas is heated in the regenerating chambers, but is preferred comparatively cool in the flues, on account of the necessity of avoiding overheating of the valves, spindles, &c. In my furnace, the gas is required to be as hot as possible on its arrival at the place of combustion. In the case of our largest furnace, the distance from the centre of the furnace to the most distant gas-producer is 260 feet, and the whole of the interior of the underground flue, which is 7 feet by 3 feet in cross section, is maintained at a red heat. This is by way of introducing the description of the two large furnaces already mentioned as having been recently erected at our new plate-mills. The heating chamber of the smaller one is 30 feet long, from end to end, and 7 feet wide from front to back; the large furnace has its heating chamber 34 feet 6 inches by 11 feet, the great width being designed to take in the 6-ton and 7-ton slabs rolled in our large mill. Both furnaces are of precisely similar construction, the only difference being in dimensions. My description will specially apply to the 30-feet furnace, that being the one represented by the drawings to which I shall have to refer, and which are as follows:—

- Fig. 9. Horizontal sectional plan on line *a-b* of Fig. 10.
- „ 10. Vertical longitudinal section on line *c-d* of Fig. 9.
- „ 11. Vertical cross section on line *e-f* of Fig. 9.
- „ 12. Vertical cross section on line *g-h* of Fig. 9.
- „ 13. Elevation of front or working side of furnace.

In all these drawings the reference letters indicate the same details of construction, viz.:—

- A Interior of heating chamber.
- B Hot air chamber between back walls.
- C Flues from cold air inlets to chamber B.
- D Flame outlet ports.
- E Cold air inlets.
- F Doorways.
- G Foreplates of doors.
- H Buckstays.
- I Shutters regulating admission of air to flues C.
- J Slag hole.
- K Gas inlet ports in upper arch of roof.
- L Flame inlet ports in lower arch of roof.

- M Hot air chamber between roof arches.
- N Chimneys.
- O Gas flue.
- P Upper arch of roof.
- Q Lower arch of roof.
- R Hand-wheel and connections for operating gas valve.
- S Gas valve.

The mode of working the furnace is as follows :—

After the whole of the brickwork of the furnace has been thoroughly dried by fires kept burning in the interior for a sufficient length of time, wood being the best fuel for this purpose, the gas is admitted through the valve S by turning the hand-wheel R, and is ignited by the fire left burning for that purpose. The process of "putting gas in" is a little different from that adopted in starting a melting furnace. In the case of the new furnaces, all the doors must be closed before the gas is admitted, in order that a thorough draught from the air inlets E to the chimneys N may be established. This effectually prevents any spreading of the gas between the roof arches, where it might cause an explosion. The gas invariably lights quietly, and without the slightest "puff." It is well not to put on the full power of the flame at first, but to heat up the furnace gradually in order that the brickwork may not be too severely tried by sudden expansion under the great heat to which it is exposed; this is especially important in the commencement of operations with a new furnace. The gas flame strikes the floor of the working chamber, and passes along it and through the outlet ports D at each end of the furnace to the chimneys, on its way passing over and along the arch of the air flues C, which it brings to a red heat. The air to support combustion of the gas is drawn in at the inlets E and through the flues C into the hot-air chamber B at back of furnace, and thence into the hot-air chamber M between the arches which form the roof of the furnace, the chambers B and M being in free communication. It will thus be seen that the gas is driven into the furnace in a descending column which is entirely surrounded by a stratum of highly heated air, the producer pressure and the chimney draught together causing the flame to enter the furnace with considerable velocity. From the chamber M the hot air passes

PLATE I.

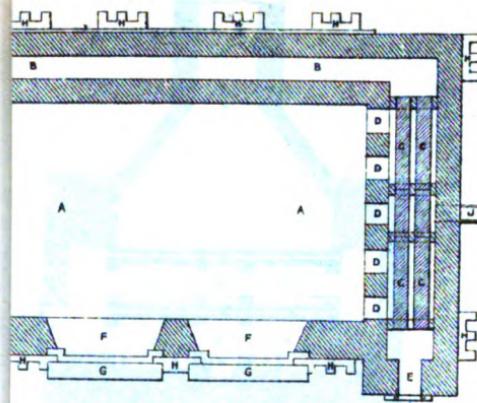


Fig. 1.

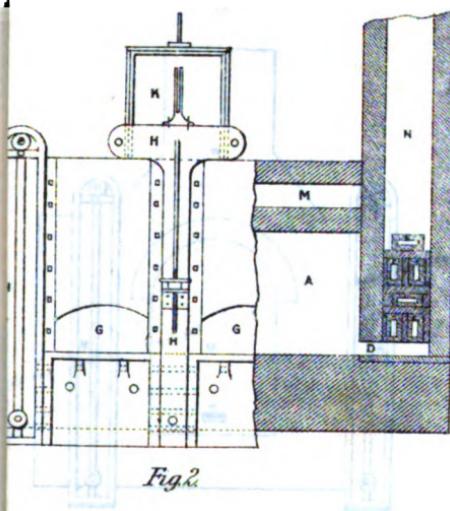


Fig. 2.

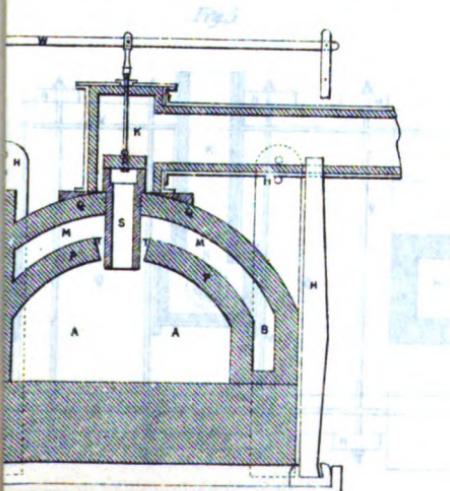


Fig. 3



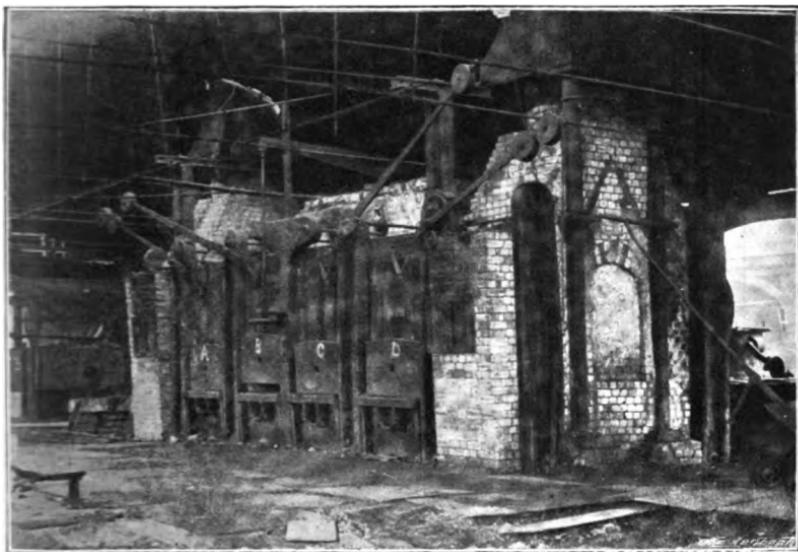


Fig. 7.

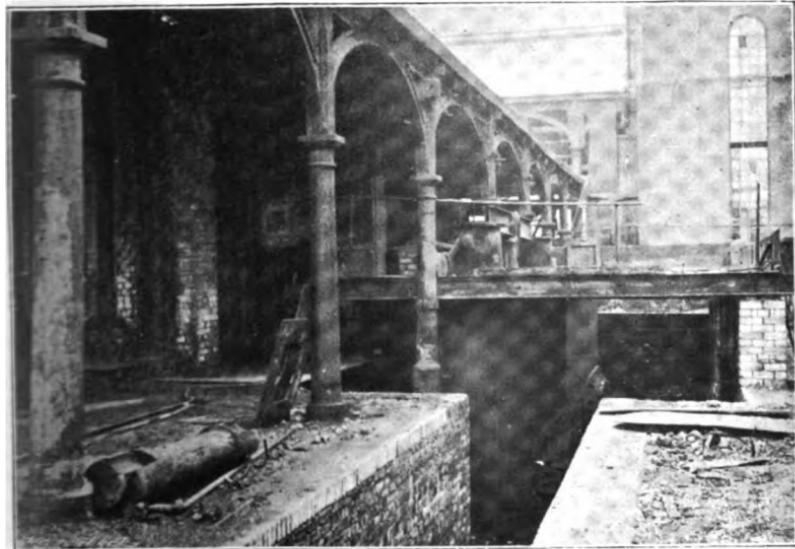


Fig. 8.

■ ■ ■

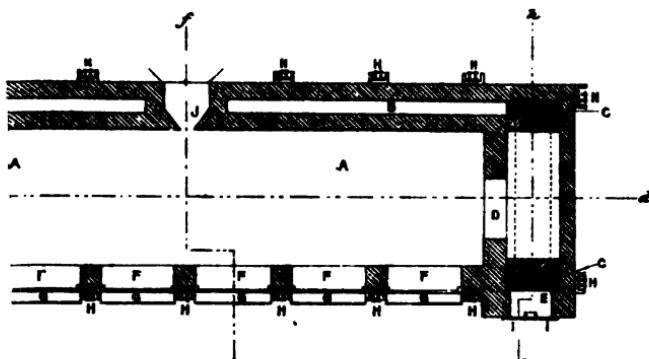
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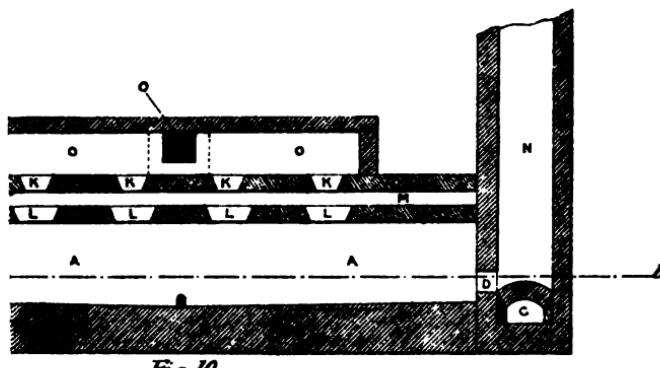
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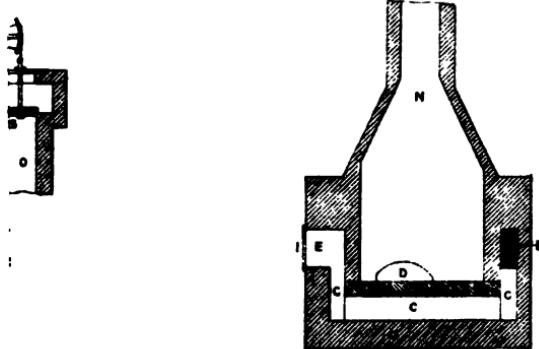
PLATE IV.



*Fig. 9.*



*Fig. 10.*



*Fig. 12.* Digitized by Google



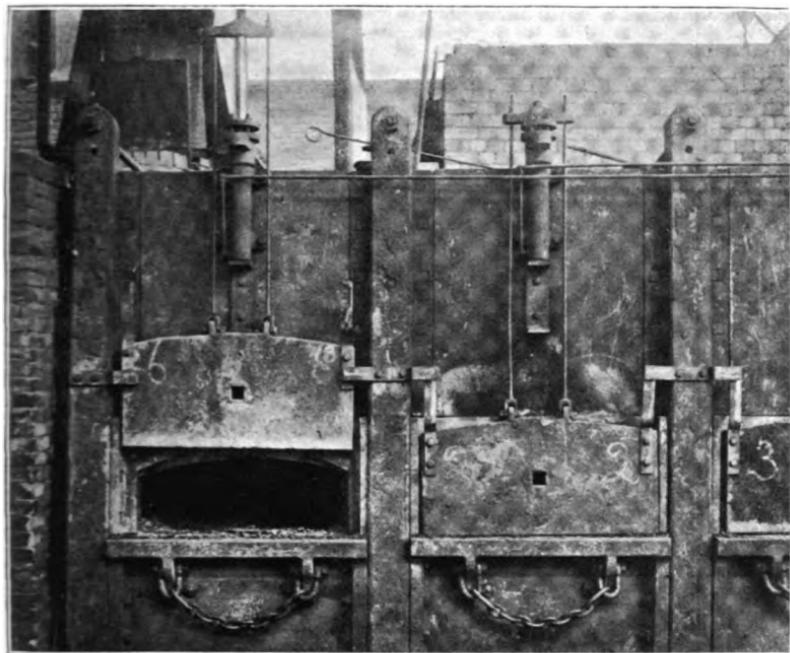


Fig. 15.

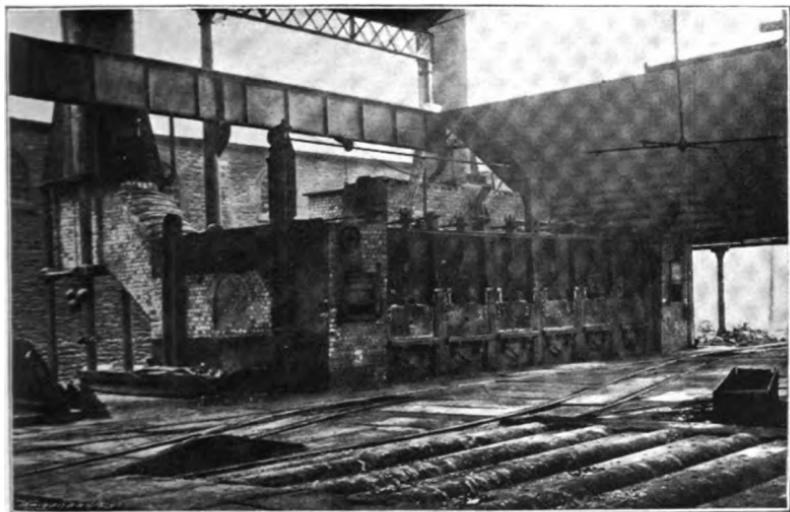


Fig. 16.



PLATE VII.

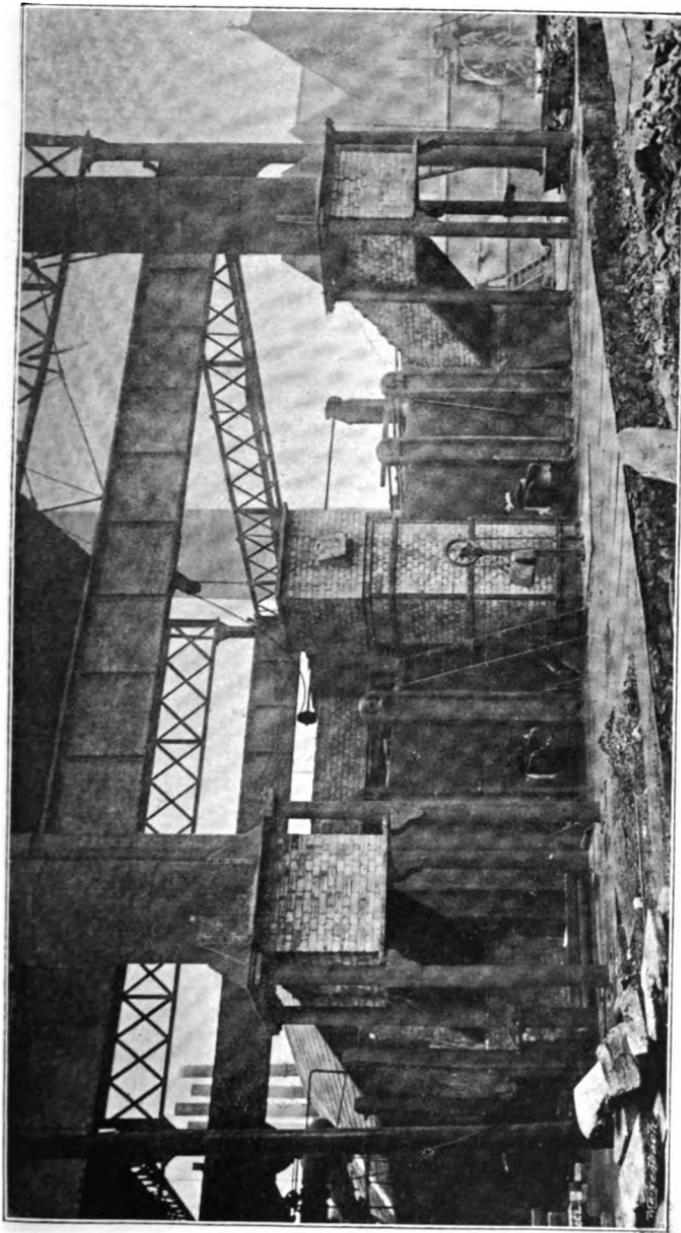


Fig. 17.



PLATE VIII.

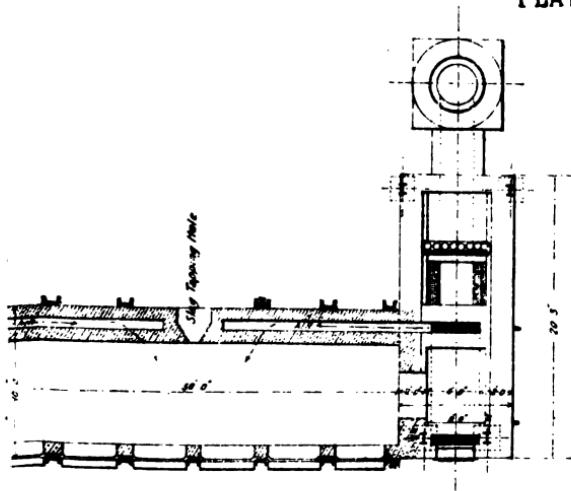


Fig. 18

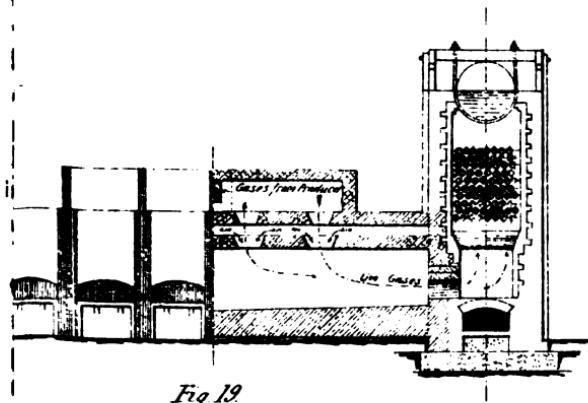


Fig. 19

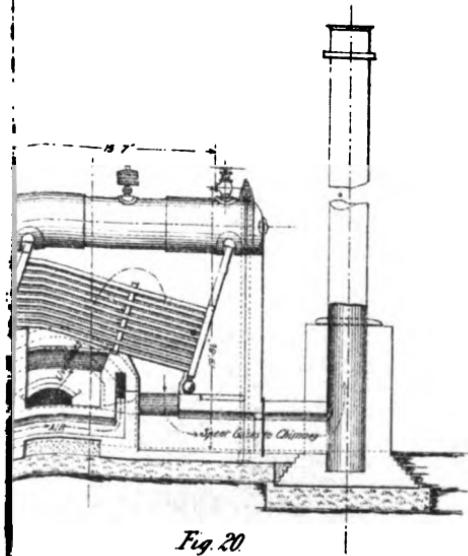


Fig. 20



with the ignited gas through the inlet ports L into the interior of the furnace, the gas burning with an intense white flame, which, in a short time, brings the whole of the interior of the furnace to a white heat necessitating the use of blue glasses for its inspection. The relative proportions of gas and air required to produce the character of flame and degree of heat desired are adjusted by the hand-wheel R and the shutters I. The chimneys N are provided with dampers at the top, by which they can be regulated either to have an equal draught, and so distribute the flame equally over the floor of the furnace, or one chimney may be allowed to have a stronger draught than the other, in which case the flame may be directed to one end of the furnace, if it be so desired, on account of the nature or progress of the work to be done. The floor of the furnace is formed so as to have an inclination to the slag-hole J, in the centre of the back wall, through which any melted slag produced flows out of the furnace, either continuously or at intervals when the stopping of the tap-hole is removed. I may here remark that in a furnace the length of the heating chamber of which exceeds 20 feet, it may be desirable to have two slag-holes instead of one, as shown in the drawings. The slag spouts are of cast steel, 2 inches thick, of U section, and about 4 feet long, so as to reach quite through the thickness of the two back walls and the space between them, where the spouts pass through, is built up solid. The steel slabs are introduced into the furnace, or withdrawn therefrom, through the doorways F by hydraulic power, bogeys of special construction for the purpose carrying them to and from the furnace upon a railway of 3 feet gauge, the motive power being small locomotive engines. The furnace doors are not lifted by counterpoised levers in the usual way, but each door is coupled to the crosshead of a small hydraulic piston moving in a cylinder bolted to a cast-iron plate above the door. Half-inch pipes take the water to and from these cylinders, and the six pipes working the six doors are brought together in a sort of table furnished with six handles, and placed quite away from the furnace, at which a boy sits within view of the chief furnaceman, and raises or lowers each door as required. A seventh handle controls the hydraulic machinery which moves the slabs into or out of the furnace. The position of this table,

and of the hydraulic gear and narrow-gauge railways, is shown upon the block plan Fig. 14, and an illustration of two of the doors is given in Fig. 15, in which will be noticed the hydraulic lifting arrangement, and also a simple plan which I have devised for holding the upper edge of the door tightly against the plate behind it when the door is down, so as to let in as little cold air as possible.

One advantage of the new furnaces, and by no means an unimportant one, is that the working bottom of the heating chamber may be formed entirely of basic slag, instead of the sand which is always used in coal-fired furnaces, and requires constant repair in order to keep the bottom in working order. In these last-named furnaces the heat is not sufficient to keep the "cinder" fluid upon a basic bottom; it assumes a treacly condition, and will not run off; but in the new furnaces it is literally as thin as water, and flows out without the slightest difficulty. The basic bottom is 10 to 12 inches thick, the whole thickness being put in at once before any heat is applied to it. The slag is broken to lumps about the size that would pass an inch mesh, and with this material the whole bottom is formed, a thin coating of smaller lumps being spread over the surface, which is, of course, laid with the required inclination to lead the fluid cinder to the tap-holes. This inclination should be not less than half an inch, or more than three-quarters of an inch, to the foot. All this is done before the drying fires already mentioned are lighted. It requires about sixty hours of the full heat of the gas flame to bring the basic slag bottom to the proper condition for charging the slabs upon, and it does not attain its ultimate hardness until it has had about a week's work of actual heating slabs, during which time the fluid cinder soaks into and fills up the interstices in the bottom. When this has been done, and the cinder begins to lie in shining pools like water along the back wall against the tap-holes, the bottom will have become as hard as granite rock, and will cause a bar striking it to rebound with a ring, as though it had struck an anvil. When this condition has been arrived at, scarcely any repair to the bottom will be required beyond filling up with small basic slag any little depressions that may appear.

One point is of great importance, and must have the most

careful attention. The fluid cinder must never be allowed to touch the brickwork of the back or end walls of the furnace, but the basic slag must be kept well banked up against the walls, so as to cover up the three lowest courses of bricks, and so make the lowest part of the floor, that is to say, the channel along which the fluid cinder collects and flows to the tap-holes, about 9 inches away from the walls. This cinder has an extraordinary solvent action upon silica brickwork, and will cut away a 9-inch wall in an incredibly short time—almost in a few minutes. As an additional precaution, I have adopted with perfect success the plan of building the three or four lowest courses of the internal walls with chrome bricks, against which a bank of small chrome ore is placed, which forms a backing for the bank of basic slag. If this course be pursued, no trouble whatever will arise.

It is worth mentioning that, in order to obtain the best results, the quantity of gas admitted into the furnace should not be more than is necessary to make the flame just pass through the outlet ports. Whenever a flame several feet high is seen at the top of the chimneys, gas is being wasted, and the heat of the furnace is being reduced. This necessitates some attention being paid to the gas inlet-valve, especially when the furnace has two producers of its own, as in the case of the one represented in Figs. 7 and 8. The gas supply varies on account of the firing-up and poking of the producers from time to time, and this should, as far as possible, be corrected by regulating the opening of the gas-valve as may be found necessary. At the small furnace last mentioned, I remarked to the foreman on one occasion, "The furnace is not working so hot as it was an hour ago." "Killing her with kindness, sir," he said; "killing her with kindness." He was quite right. The flame had been pouring out at the top of the chimneys, and the furnaceman had not noticed it.

Fig. 16 is an illustration of the front or working side of our large furnace. It may be observed that the hand-wheel by which the gas-valve is controlled is at the end of the furnace instead of in the middle of the front, and that the connection between the wheel and the valve is made by means of a vertical revolving shaft, worm-wheel and screw, horizontal shaft, chain, and pulley, instead of the simple lever arrangement shown in the drawings. This alteration was made to obviate the inconvenience of the

hand-wheel becoming too hot to be comfortably handled in the former position, and also to place it more out of the way of the operations conducted in front of the furnace. The chimneys are not placed over the centre of each end of the furnace, as shown in the drawings, but at the back, in order that they may not obstruct the working of an overhead travelling crane.

Fig. 17 shows the back of the 30-feet furnace. The main gas-flue will be noticed in the centre: on each side of it are the slag-holes and the chimneys.

However carefully the gas supply may be regulated, there will inevitably be a large amount of heat lost beyond that actually utilised in doing the work of the furnace. I proceed to show how this waste—probably not less than one-half of the calorific value of the coal consumed in the producers supplying gas to the furnace—may be made use of as a valuable means of raising steam. Those who are familiar with the modern water-tube boilers—notably the well-known type manufactured by Messrs. Babcock & Wilcox—will be prepared for my saying that the flame-chamber at each end of the furnace is admirably adapted for containing the water-tubes of such a boiler, the steam-drum being placed directly over the chamber, as shown in Figs. 18, 19, and 20, which I have photographed from drawings most kindly furnished to me by Messrs. Babcock & Wilcox, to whom I beg to express my obligations. These drawings represent our 30-feet furnace fitted with a boiler at each end, Fig. 18 being a plan amplified from that given in Fig. 9; Fig. 19 a half elevation and half longitudinal section, from Figs. 10 and 13; and Fig. 20 a vertical cross section from Fig. 12. Each of these boilers would have a heating surface of 1455 square feet, and would be capable of evaporating 4200 lbs. of water per hour, and would be more than equal to a two-flued Lancashire boiler 30 feet long and 8 feet diameter, the heating surface of which is about 975 square feet, of which 540 feet represents the heating surface of the two internal tubes by which the greater part of the work is done, and 435 feet the heating surface in the side flues and bottom flue together. I believe I may safely assume that four of the water-tube boilers, fired, as I have described, by the waste heat of two furnaces, would be equal to five of our Lancashire boilers, each of which, when entirely hand-fired, requires 53 tons

of coal per week. We may therefore take it that the saving of fuel effected by the waste-heat utilisation would be 265 tons of coal per week. Our two furnaces at the plate mills are driven by five producers of Mr. Bernard Dawson's most recently patented design, each producer burning from 6 to 8 cwt. of coal per hour, according to the quality and condition of the coal and the pressure of the forced draught. We have worked them with four producers, but I prefer to use five moderately pressed rather than four driven to their full power. Taking 132 as the number of working hours per week, and 8 cwt. as the maximum hourly consumption, we have 52 tons 16 cwt. as the weekly consumption of each producer, or 264 tons per week for the five producers. We have seen that the coal required by five Lancashire boilers raising as much steam as the four waste-heat boilers referred to would be 265 tons per week; so that we have now arrived at the satisfactory result of raising steam and heating the slabs for the mill with the quantity of coal otherwise required for raising steam alone; and I do not see any escape from the conclusion that if we have the furnaces and boilers as described we can heat our slabs without cost.

Putting aside now the question of boilers, it has been seen that the two furnaces are driven with 264 tons of coal per week as the maximum quantity consumed. Taking the output of the two plate mills at 1650 tons per week—a figure well within their capacity—we have a coal consumption of 3·2 cwt. per ton of sheared plates, or about  $2\frac{1}{4}$  cwt. per ton of slabs heated. The output aforesaid, 150 tons per shift, does not represent the full power of the two furnaces, but about two-thirds thereof, if they be worked for a whole shift with fairly heavy slabs. For example:—The large furnace can heat 36 5-ton slabs, = 180 tons; and the smaller furnace 36 70-cwt. slabs, = 126 tons; together, 306 tons per shift. Of smaller slabs, e.g., 30 cwt., either furnace can heat 60, = 90 tons; or, for both furnaces, 180 tons per shift.

Coming now to the last, but not the least important division of my subject, viz., the first cost of the furnaces, I venture to express my belief that by their adoption an amount of reheating power in proportion to original outlay, and notably in proportion to cost of maintenance, can be obtained beyond what has been previously accomplished. I have before me minute details

of the cost of our two plate-mill furnaces. The large furnace has cost £529 and the smaller one £432. From these figures it will be apparent that the larger the furnace the less is its cost in proportion to its heating power. In the large furnace, the area of heating-chamber floor is 379·5 square feet, and the cost is £1, 7s. 10d. per square foot. The smaller furnace has an area of 210 square feet, and its cost is £2, 1s. 1d. per square foot.

If these two furnaces had been furnished with the water-tube boilers of Messrs. Babcock & Wilcox, according to the design which I have illustrated by Figs. 18, 19, and 20, the cost would have been, for the large furnace and two boilers, £1500; and for the smaller furnace and two boilers, £1400.

I have it in contemplation to adopt the four boilers as specified, although that would involve the disuse of five out of our eleven new Lancashire boilers. I now heartily wish that the success in the preliminary furnace experiments, which has so amply justified our adoption of the method of reheating, which I have at so great length described, had been realised before our new boilers were put down. I must, however, confess that the peculiar adaptability of the new furnaces to the working of water-tube boilers is one of their advantages which had not presented itself to my mind in time to be carried into effect as a part of our new plate-rolling plant.

*DISCUSSION.*

Sir LOWTHIAN BELL, Bart., Past-President, commenting on the paper, said that he had listened with much pleasure to the paper, as he had no doubt all those present had done. From it he gathered that a more perfect combustion of coal was necessary by the new form of furnace described than was or probably could be found necessary in furnaces of the old construction. That all sought to get the greatest possible amount of heat out of the coal needed no lengthened argument for him to prove, for, as all knew, the quantity of heat evolved by a unit of carbon in the form of monoxide was only about one-third of that evolved from the same unit of carbon oxidised to dioxide. But there was another question to be considered, and he would observe that his view of the question was more or less proved by the observation of the phenomena attending the consumption of coal in the two cases. In the ordinary furnace there was a large flag of flame issuing from the top of the chimney, but it was not to be supposed that the flame was generated in the heart of the furnace itself. The partially oxidised portion of the carbon found its way up the chimney, and ignited at the top, where it met with atmospheric air. This was a mere repetition of what happened in the blast furnace itself, where about two-thirds of the carbon monoxide generated in the zone of fusion did not ignite until it came in contact with atmospheric oxygen, the remaining third being converted into carbon dioxide by the reduction of the ore.

Mr. GEORGE AINSWORTH said he wished to bear testimony to the excellent way in which the furnace appeared to do its work. He had had the privilege of seeing both the first smaller furnace and the later large one at the Spennymoor Works heating slabs, and he could not but be struck with the beautiful mild heat at which they were brought out of the furnace, and the comparatively short time it took to bring them to that temperature. Having only seen the furnaces casually for a very short time, he could not say anything as to the economies beyond what Mr. Hollis

had stated—in fact, not so much ; but as to the furnace doing its work in a very nice, pleasing, and effective fashion, he could give his personal testimony ; and as regarded the building of the furnace generally, and the mechanical appliances connected with it, they were only such as might be expected from what they knew of Mr. Hollis's perseverance and mechanical skill.

Mr. ANDREW LAMBERTON said he was sure Mr. Hollis's communication would be regarded with great interest by all makers of steel products. He (Mr. Lamberton) must apologise for taking part in the discussion at so early a stage, as he was sure others more competent than himself were desirous of speaking ; but his excuse was that he occupied a rather favourable position for saying what he desired to say.

He had been honoured by the Weardale Company in being selected to put down their entire new plate-mill plant, and during the construction of that plant and its erection there, he had the opportunity from the very first of seeing Mr. Hollis's experiments with the initial furnace, and subsequently his successes with the larger furnace. He confessed that when they were nearing the time when the plant was to start as a complete installation, and take up the whole output of the works, he experienced some slight misgivings when he understood Mr. Hollis meant to put down only his special furnaces, without anything in the way of a standby. He experienced some fear lest anything might turn out not quite what was expected, and the whole success of the initial starting of the plant thereby suffer. He was glad that he kept these fears to himself, because, when it came to the time of starting, Mr. Hollis, who had, to use a vulgarism, "gone nap" upon his two furnaces, won easily and handsomely.

He had never seen slabs presented to plate-rolling mills so well heated as those that were now being heated in the Weardale works ; they were beautifully soft and free from that dread of all rollers—bone in the middle. Altogether the success which had attended the heating of the slabs in these new furnaces had been of the most marked character. He had great pleasure in giving practical testimony, as it might be termed ; others were more capable of going into the subject from scientific standpoints, such as those touched upon by Sir Lowthian Bell.

He took it for granted that Mr. Hollis's figures would bear investigation, and if they did, he thought it was not too much to say that the "Weardale" furnace stood to-day practically in the forefront of our heating furnaces—for slabs, at any rate. He did not think that in Scotland slabs were heated with less than 5 cwt. of coal per ton of sheared plates; but it appeared from Mr. Hollis's paper that he did it for 3·2 cwt. of coal.

He had great pleasure in congratulating Mr. Hollis on the success which had attended his furnace, and he hoped that he would forgive him for having at one time experienced those craven fears to which he had alluded, and which had been proved to be so unfounded.

Mr. W. DEIGHTON had once or twice had the opportunity of examining the furnace which the author had described in his paper. In watching the working of the furnace, what struck him was the enormous temperature to which the air was heated. They could imagine the gas as it passed through the Siemens furnace entering the port in the opposite direction possessing the high temperature it did. He had not the slightest hesitation in saying, from his own observation, that Mr. Hollis showed him a temperature of flame equal to that of the Siemens furnace. It could readily be understood how the air was heated to that high temperature, because that intensely-heated flame passed over the flue directly the air entered it. He had suggested to Mr. Hollis—and he was sorry that he had not found it convenient to adopt the suggestion—that he should ascertain, if possible, the temperature of the air as it entered the gas-port. He could also bear out the remarks made by Mr. Lamberton as to the heating. He was very much struck with the non-oxidation of the slabs. One could watch for an hour, and see them come out practically free from oxide. He had never in his life seen slabs heated as they came from that furnace, and that he took to be a most remarkable feature of the furnace. Mr. Hollis had made some remarks about the introduction of water-tube boilers, but he (the speaker) would not like to be one of the tubes of that boiler to stand the enormous temperature; he would rather be a great deal farther away from it. No one, he was sure, would regret undertaking the journey of going to see the furnace at work.

and he would recommend every manager to go and see it if possible.

Mr. ALEXANDER E. TUCKER said that the object of the introduction of basic slag bottoms, mentioned in the paper, was to substitute a neutral material for the sand commonly used. Mr. Hollis had already verbally corrected one statement in his paper, namely, "that in coal-fired furnaces the heat is not sufficient to keep the 'cinder' fluid on the basic slag bottom; that it assumes a treacly condition, and will not run off." They had a large number of furnaces so lined—150 or 160—the majority of them working in coal-fired furnaces, and the fact of their being in constant use during a period of nine or ten years was a proof that they were a practical success. He wished also to correct a statement in the paper in connection with the use of chrome ore. They had found that chrome joints were not at all necessary. In practice they simply removed the course of bricks immediately above the hearth, and rammed in either some old cinder from the basic slag lining, or some of the ordinary basic slag or basic material. In each case the success was perfect, and no solvent action such as that indicated by Mr. Hollis took place.

Mr. F. W. PAUL said it was not his intention to have taken part in the discussion, but as he had seen the furnace at work, he gladly availed himself of this opportunity of thanking Mr. Hollis for his paper, and he had pleasure in fully endorsing what had been said by other speakers as to the efficient way in which the furnace heated slabs. One important economical point, however, yet remained to be settled—that of the amount of fuel necessary to heat a ton of steel, with the amount of water which would be evaporated per pound of fuel consumed when the waste gases were conducted through a boiler.

Judging by the results of numerous trials which he had investigated of various boilers worked in conjunction with heating furnaces, he did not feel sanguine that Mr. Hollis would realise his contention that it would be possible "to raise steam and heat slabs for the mill with the quantity of coal otherwise required for raising steam." Fuel burnt direct in modern Lancashire boilers evaporated eight to nine pounds of water per pound of fuel,

whereas his experience of numerous types of boilers, when heated by waste gases from heating furnaces, only gave an evaporative efficiency of about 50 per cent. of above on total coal consumed.

If, however, Mr. Hollis realised a higher evaporative efficiency than this when he completed his arrangements with a Babcock boiler in connection with a heating-furnace, he had no hesitation in saying that he preferred Mr. Hollis's furnace to any which he had ever been privileged to see working.

As regarded Mr. Deighton's apprehensions, he could assure Mr. Hollis that there was no difficulty or trouble in working a Babcock tubular boiler in connection with the waste gases from heating-furnaces, and he arrived at that conclusion from the experience which he had had with a Babcock boiler very similar to the proposed arrangement.

Mr. H. W. HOLLIS, in reply, said that Mr. Deighton had made some reference to the question of temperature. Since coming into the room, he had received a telegram giving the temperatures received that morning from a furnace that had been working gas put in the previous day about midday, so that it was scarcely up to full heat at the time when the results were taken. The temperatures were ascertained by means of an ordinary Siemens copper-ball pyrometer. The air between the furnace-roof arches was from 850° to 1000°. The temperature of the gas in the up-take at the back of the furnace was 1250°. The temperature of the outgoing current at the base of the chimney was—he did not know what, but something over 2000°, because it melted the copper-ball. He thought that disposed of Mr. Paul's suggestion about whether there would be temperature enough left to be worth putting a boiler for. Mr. Tucker had mentioned that chrome ore was not necessary. Perhaps it was not, but he liked to be on the safe side. He wished to say a word upon the question of the cost of repairs. In the last seven months during which the furnaces had been at work, about 20,000 tons of slabs had gone through those two furnaces, and the cost of repairs, which had been very accurately ascertained, was 1·08 pence per ton of finished sheared plates, or about three farthings per ton of slabs heated. He thought it would be admitted that that was a satisfactory result.

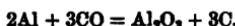
The PRESIDENT moved a hearty vote of thanks to Mr. Hollis for his very practical paper. He was sure they were all delighted to find that those who were making steel plates would be able by the use of the "Weardale" furnace to save 2s. 2d. per ton in fuel alone.

The following paper was then read :—

## ON THE PERMEABILITY OF STEEL-MELTING CRUCIBLES.

By J. O. ARNOLD AND F. K. KNOWLES,  
RESPECTIVELY PROFESSOR AND DEMONSTRATOR OF METALLURGY AT THE  
SHEFFIELD TECHNICAL SCHOOL.

IN a lecture delivered by one of us before the Sheffield Metallurgical Society in February 1891, it was pointed out that on passing pure carbonic oxide over white-hot aluminium, the metal became coated with a grey mixture of alumina and carbon, owing to the following reaction :—



It was also shown that on blowing forty gallons of carbonic oxide through molten mild steel containing about 4 per cent. of aluminium, that the carbon was raised from 0·38 to 0·51 per cent.

The power of aluminium to reduce carbonic oxide at high temperatures above exemplified has since been utilised to measure the remarkable permeability of clay steel-melting crucibles to furnace gases.

The experiments were carried out as follows. Four 25-lb. ingots were melted from (A G) Swedish iron of the following percentage composition :—

Combined carbon . . . . .	0·04
Silicon . . . . .	0·02
Manganese . . . . .	0·06
Sulphur . . . . .	0·01
Phosphorus . . . . .	0·02
Iron . . . . .	99·85

The following calculated quantities of aluminium were added to the ingots when melted :—

	Time Occupied in Melting.
No. 1. 4 oz. = 1 per cent. . . . .	$5\frac{1}{2}$ hours.
„ 2. 8 „ = 2 „ . . . . .	6 „
„ 3. 12 „ = 3 „ . . . . .	6 „
„ 4. 12 „ = 3 „ . . . . .	$5\frac{1}{2}$ „

These ingots were broken up and remelted, the weights charged

being—of Nos. 1, 2, and 3, 21 lbs.; of No. 4, 17 lbs. Time occupied in second melting :—

No. 1.	5 hours	10 minutes	These ingots were molten some time before teeming.
" 2. 5 "	25	"	
" 3. 5 "	40	"	
" 4. 6 "	0	"	

In the case of No. 4 ingot, the charge was molten three hours before teeming, and during this time 3 lbs. of sulphide of iron were mixed with the coke used in firing (bringing up the sulphur in the coke to 1·75 per cent.).

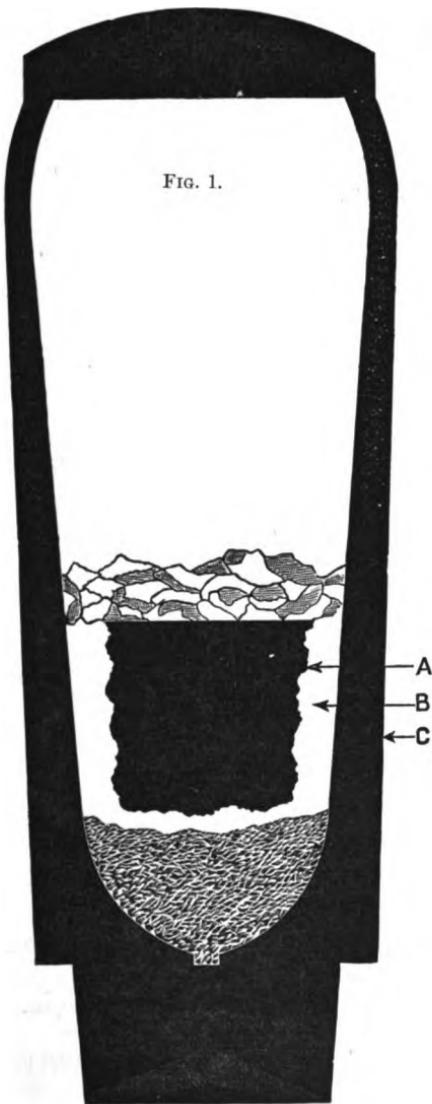
The following table gives the composition of the ingots before and after melting :—

	CC.	Al.	Si.	Mn.	S.	P.	Fe.
No. 1. { 1st melting	0·06	0·64	0·03	trace	0·02	0·02	99·23
	2nd ..	0·62	0·08	...	0·03	0·019	99·15
No. 2. { 1st melting	0·06	1·80	0·03	...	0·02	0·02	98·07
	2nd ..	0·89	0·07	0·22	...	0·03	0·017
No. 3. { 1st melting	0·06	2·25	0·08	...	0·02	0·02	97·62
	2nd ..	1·02	0·20	0·04	...	0·03	0·019
No. 4. { 1st melting	0·06	2·22	0·10	...	0·025	0·021	97·57
	2nd ..	1·00	0·20	0·50	...	0·06	0·019
							98·22

It will be seen that in each case the greater part of the aluminium has been oxidised, and that the carbon liberated has converted the iron into hard steel in one case (No. 4) remarkably high in silicon, doubtless reduced from the clay of the crucible during the prolonged time the steel was maintained in a molten state.

The most important practical feature of the experiments is the fact that the walls of a crucible form little protection against the absorption of sulphur by the metal inside it. On melting the original alloy the sulphur has doubled (viz., 0·01 to 0·02 per cent.); on the second melting it has risen to 0·03 per cent.; whilst with a very bad coke (containing about 2 per cent. S) it has risen to no less than 0·06 per cent. In other words, an analyst would deny that it was melted from good Swedish material. (It is, however, a curious fact that during the melting of an ordinary ingot sulphur was kept burning under the furnace-bars, and to the authors' surprise no unusual increase was detected in the sulphur of the ingot.) A feature of the table worthy of

notice will be found in the phosphorus column. The authors have satisfied themselves that the minute decrease noted is not due to the errors of analysis, but to the basic action of the



alumina. The latter is very large in volume, and occurs partly in loose pieces on the surface of the molten steel, but mainly in

the form of a second inner crucible, as shown in Fig. 1. A is the steel, B the self-formed crucible of alumina, C the clay wall of the original crucible. Of course, during the melting the precaution was taken to keep the crucible covers luted on so as to prevent surface absorption.

The subjoined figures show that the reaction is not due to carbonic oxide alone, but to a mixture of carbonic oxide and carbonic anhydride, and possibly oxygen drawn in through the walls of the crucible by the suction due to a partial vacuum caused by the continual absorption of the gases by the aluminium :—

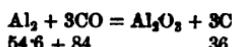
Theoretical Increase of Carbon, Calculated from Aluminium Lost.	Actual Increase.
No. 1 = 0·37 per cent.	0·56 per cent.
.. 2 = 1·14 .. . . . .	0·83 ..
.. 3 = 1·36 .. . . . .	0·96 ..
.. 4 = 1·34 .. . . . .	0·94 ..

*The final result is the carbonisation of iron to steel in a closed crucible by the gases of the furnace. The volume of carbonic oxide (CO), or of a mixture of carbonic oxide and carbonic anhydride (CO<sub>2</sub>), which must have passed through the walls of the crucible\* in the respective ingots are as follow :—*

No. 1. Gallons of CO (or xCO + yCO <sub>2</sub> ) at 1600° C.	= 128
.. 2. .. .. .. ..	= 186
.. 3. .. .. .. ..	= 219
.. 4. .. .. .. ..	= 177 (17 lbs. ingot).

The calculations giving the above figures were made as indicated in the following example :—

#### No. 1 Ingot.



Weight of ingot, 21 lbs.; carbon increase, 0·56 per cent.

$$\therefore \text{weight of carbon taken up} = \frac{.56 \times 21}{100} = 1\cdot176 \text{ lbs.}$$

84 lbs. CO yield 36 lbs. of C.

$$\therefore \frac{84 \times 1\cdot176}{36}, \text{ or } 0\cdot2744 \text{ lbs. CO yield } 1\cdot176 \text{ lbs. C.}$$

1 lb. (avoird.) = 453·584 grams.

$$1 \text{ litre of CO} = (.0896 \times 14) = 1\cdot2544 \text{ grams.}$$

$$\therefore 0\cdot2744 \text{ lb. CO} = 124\cdot4635 \text{ grams.}$$

$$\text{and } 0\cdot2744 \text{ lb. CO} = \frac{124\cdot4634}{1\cdot2544} \text{ or } 99\cdot221 \text{ litres.}$$

1 litre = 0·22 gallon.

$$\therefore 99\cdot221 \text{ litres} = 21\cdot828 \text{ gallons at } 0^\circ \text{ C.}$$

= 128 gallons at 1600° C.

\* The thickness of the crucibles used was about three-quarters of an inch.

Typical mechanical tests of the materials are given in the subjoined table:—

*No. 3 Steel.—Tensile Tests, 1 $\frac{1}{4}$  inch square rolled to 1 inch round.*

	After 1st Melting.	After 2nd Melting.
Elastic limit . . .	20·48 tons per square inch.	28·22 tons per square inch.
Maximum stress . . .	29·83 " "	47·90 " "
Elongation in 2 inches	11·8 per cent. " "	16·0 per cent. " "
Reduction of area . .	12·3 "	26·4 "
Fracture . . .	Bright crystalline.	Granular, with dark centre.

The aluminium alloys rolled well, but the *steels* were very “dry” and “tender” in the rolls, so much so that some care had to be exercised to obtain sound pieces of the bars for the mechanical tests. This effect is probably due to the fact that it was difficult to teem the ingots without involving some of the dry powdery alumina in their structure.

The results just described will convey to makers of high-class crucible steels working to stringent chemical specifications a clear idea of the importance of insisting upon the sulphur in their coke being reduced to the lowest possible percentage, otherwise the purest Swedish bar irons may melt out seriously high in this objectionable element, owing to the crucible being permeated by the sulphur dioxide ( $\text{SO}_2$ ) present in the furnace gases in considerable quantity when impure coke is employed in melting the charge.

*DISCUSSION.*

Professor ROBERTS-AUSTEN, C.B., Member of Council, said it was a happy thought of the authors of the paper to bring home to manufacturers the fact that the crucibles they employed were porous. At the present day they were apt to forget that the permeability of crucibles by furnace gases was a dominant question in the minds of metallurgists early in the century. When Bergmann, at the end of the last century, showed that carbon was the real cause of the difference between steel and iron, people at once turned their attention to the question of the source of the carbon which carburised the iron, and consequently to the permeability of crucibles, and to the action of furnace gases. They might trace the anxiety on the point running through the works of Clouet, Guyton-Morveau, and Mushet.

The great and almost the last defence of the theory of phlogiston turned on the carburisation of iron; and Professor Austen said he might refer to a little paper published in the Proceedings of the Institution of Mechanical Engineers in 1881, which stated that Kirwan in 1787 said that "if a bar of iron be put into a crucible, well covered and heated without any addition, and kept at a welding heat for eleven days, it will be converted into steel." Here "it is plain that charcoal could not penetrate through the crucible, but fixed air easily can. . . . The plumbago, then [or carbon] clearly owes its origin to this [fixed] air, as Mr. Bergmann explains it." That was an interesting historical note. In several industries other than that of iron and steel they recognised the porosity of crucibles. In fact, in Miller's process for separating silver from gold by chlorine gas, the porosity of the crucible was so great that they were obliged to saturate it with borax, for fear the fusible chloride of silver should run through the walls. In some experiments recently made at the Mint in melting silver in a vacuum, the whole crucible being contained in a vacuous vessel and heated by electricity, it was found that a converse action took place, and that the silver melted in the crucible transpired through its porous wall. They had therefore abundant instances of the interesting fact that the authors had done so well to bring home to the knowledge of manufacturers.

Mr. J. E. STEAD, Member of Council, thought it was a very important thing that the matter should be brought before crucible steel-makers, because the amount of sulphur likely to be absorbed was a very serious thing. Many years ago he was making investigations with aluminium pig iron, melting it in a crucible. After keeping it at a tolerably low temperature for a long time, he found formed round the piece of pig iron a coating of alumina with graphite carbon which could not be absorbed by the iron because it was already saturated. It remained therefore on the outside together with the alumina, and formed a compact covering about the surface. When the temperature was raised to the melting-point of the metal, it melted inside the solid coating, but could not flow down. He was surprised to find the piece of iron exactly in the same shape as it was when cold before heating. The coating was caused by the porosity of the crucible and the passage of carbonic oxide and other oxidising gases through the pot, and possibly also through the joint of the crucible cover, the carbonic oxide and carbonic acid oxidising the aluminium, which formed a deposit of alumina and carbon.

There was one point that he thought needed further investigation, namely, the peculiar change which took place between the aluminium and the carbonic oxide. It was remarked by the authors that the theoretical increase of carbon calculated from aluminium lost was 0·37 per cent., whereas the actual increase was 0·56 per cent., and so on; but in addition to the increase of carbon it appeared from the analysis given in the paper that silicon was also materially increased. The authors had calculated from the aluminium lost, assuming that it acted entirely upon the carbon-containing gases, but as a matter of fact it must have acted very materially upon the silica of the crucible. It was known that aluminium in iron acted very rapidly upon silicious matter and was converted into alumina, the silica being reduced to silicon and passed into the iron. If, then, a portion of the aluminium was used in reducing the silicon, there must be some other cause for the great increase in the carbon. What was the cause of that high carbon increase? Of course it must be from the gases passing through the crucible side, but it would be interesting to ascertain what the actual reaction was.

He was inclined to believe that a similar action to what took place in the blast-furnace when carbonic oxide came in contact with oxide of iron where carbon was actually deposited, might perhaps account for the great increase of carbon in Professor Arnold's experiments. He considered it was worth while to follow the matter up. He thought it was satisfactory to know that practically no sulphur was absorbed from the coke gases in ordinary crucible practice, when there was absent any element like aluminium which acted like a powerful pump to draw in gases from the furnace.

Mr. GEORGE J. SNELUS, F.R.S., Vice-President, had had the pleasure of reading the manuscript of the paper when it was submitted for the consideration of the Council, and he had been very much struck with the new fact that had been elucidated with regard to the action of aluminium in causing a deposition of carbon in the steel; but he thought it was probable that the increase of carbon had arisen partly from another cause. The authors had referred to clay crucibles; he did not know whether they were really plumbago crucibles or not. If they were pure clay with no carbon, of course his argument fell to the ground, but if they were as ordinarily used for steel-melting purposes, ordinary plumbago crucibles, there was no doubt that some of the carbon would come from the walls of the crucible as well as from the gases. But the important fact of the permeability of crucibles to those gases was certainly a very remarkable one, and had been placed clearly before them by the authors, to whom he begged, on behalf of the members, to offer their thanks for having brought the matter before the Institute. He thought that Professor Arnold especially deserved the best thanks of the Institute for doing so much in several directions for bringing forward erudite matters of that kind, and placing the results of his observations before the Institute.

Professor H. BAUERMAN said the paper was a very interesting one, and that the subject had been very well worked out, and left very little to be said on the matter; but there was perhaps just one point that Professor Arnold had not noticed, viz., how the crucibles were made; whether or not they were made in the

ordinary Sheffield way of using some coke in them, when there might be possibly air passing through them, which might have taken a little carbon out of the walls of the crucibles, supposing it to be there. But he had no doubt that the great mass of this carbon did come from the furnace gases. The moral of the matter, of course, was to keep the sulphur as much as possible out of the fuel used in crucible-melting, and that, he thought, led them to the consideration of what was a very important thing in these days—*i.e.*, gas-melting. This was a very important matter, and one had to consider the substitution, as far as possible, of gas-melting for coke-melting, especially if washed gases could be had, which would do away with the sulphur difficulty. Up to the present, the method of using gas in Sheffield had not been perfect, but he thought it must come in the future, and the washing of gas would be of immense importance in keeping the sulphur out.

Sir LOWTHIAN BELL, Bart., Past-President, continuing the discussion, said that in reference to the question of the permeability of clay crucibles by carbonic oxide, he might mention a point rather germane to the matter that occurred in connection with a flue some years ago, along which the furnace gases were conveyed in order to be used either for heating the stoves or firing the boilers. He was surprised to find the firebricks split; but on coming to examine the brick itself, he found, as was not at all an uncommon occurrence, that the firebricks contained minute specks of oxide of iron, and the carbonic oxide passing through the brick encountered, of course, these specks of oxide of iron, thereupon following the phenomenon which he had described more than once, of the power of oxide of iron of splitting the carbonic oxide into carbon dioxide and carbon, this being known by the deposition of the carbon. This split the brick exactly in the same way as bricks were liable to be split which contained quicklime. The moisture, of course, easily passed into the interior of the brick, and, as all knew, the occurrence of quicklime in a brick caused fracture, the expansion of small fragments of lime into hydrate of lime being the cause of the rupture, and in the same way the deposition of the solid carbon in the interior of the brick forced the sides of the brick asunder and split it.

Mr. BERNARD DAWSON said that the trouble with sulphur was not confined to steel-pot melting in crucibles. It appeared to be assumed that there would not be the trouble of carbon getting into the charges, or the trouble with sulphur, except at the high temperature at which steel was melted. He had had some experience at Birmingham in melting what was commonly called "one and one," viz. German silver, or a compound of copper and nickel, at a lower temperature than steel was melted at; but there was the same difficulty with the sulphur and the impurities from the coal. He had also had some experience with pot-furnaces melting brass, and had found it stated that even at such a comparatively low temperature as this, sulphur was gained by the metal poured from the pots. He only wished to point out that the difficulty of the permeability of crucibles was not confined to the high temperature of the steel "Coke-Hole" or "Huntsman" furnace, nor only to clay crucibles, as it was said by users of plumbago crucibles that this occurred occasionally, and was also the case with crucibles of the material made by Mr. Waterhouse, which for this purpose might perhaps be considered as being something between a clay crucible and a plumbago one of the Morgan type.

Mr. JOHN PATTINSON, Newcastle-on-Tyne, said that, as a further corroboration of the possibility of gases permeating crucibles, he might mention that not only did those gases permeate the fireclay crucibles or the crucibles used in the cases described, but that even platinum crucibles were, under certain circumstances, permeated by carbonic oxide or other reducing gas. That had been proved to him in some experiments in heating oxide of manganese at a very high temperature with the blow-pipe. The bottom part of the oxide of manganese was distinctly deoxidised, while the upper part was left in an oxidised condition, proving that the gases had permeated the bottom of the platinum crucible.

*CORRESPONDENCE.*

Mr. R. A. HADFIELD, Member of Council, considered that Professor Arnold and Mr. Knowles had by their excellent paper specially emphasised a want which was felt, not only by makers of crucible, but of other steels, viz., a coke containing a low percentage of sulphur. As they had a large number of coalmasters on the roll of membership, it was to be hoped that some of them would see the importance of this matter being taken up to aid steelmakers, who almost every year were called upon to fill more stringent specifications as regarded materials of very high purity. It did seem most wasteful and anomalous that very high prices should be paid for the most expensive Swedish iron brands, and then, owing to low quality of fuel, much of what had been striven for, namely, the production of a very pure material, was entirely undone during the melting process. He thought they were much indebted to the authors for bringing that subject home by such a clear set of experiments, and after which there would be no excuse for stating that there was any mystery as to the cause of the extraordinary rise of sulphur which had often been found to occur in the manufacture of crucible steel.

Mr. E. H. SANITER stated that, in connection with the matter brought forward by the author, it might be of interest to mention an example met with by himself. The object of his (Mr. Saniter's) experiment was to prepare pure carbide from pure peroxide of iron. An ordinary salamander crucible (fireclay and graphite) lined half-an-inch thick with pure lampblack was used. Owing to the peroxide being reduced in the form of shot, it was remelted five times to obtain a good button, which had the following composition :—

	Per Cent.
Carbon . . . . .	2·89
Silicon . . . . .	0·75
Sulphur . . . . .	0·40

The crucible was heated in a coke furnace, but was always closed by a lid, so that there was an absorption of 0·40 per cent.

sulphur from the furnace gases and 0·75 silicon, which had come through the  $\frac{1}{2}$ -inch lining of lamp-black from the crucible.

Professor J. O. ARNOLD and Mr. KNOWLES, in reply, expressed their thanks to the gentlemen who had taken part in this discussion for the interesting historical and practical facts they had brought forward. With reference to the abnormal carbon contents of No. 1 steel, to which Mr. Stead had called attention, the authors could not at present offer any certain explanation. Mr. Stead's suggestion, however, seemed very probable.

In reply to Mr. Snelus and Professor Bauerman, the authors regretted that their failure to give the composition of the crucibles had led to a little misunderstanding. The crucibles used were made from an ordinary mixture of Stourbridge, Derby, and Stanington clays, together with 20 per cent. of china-clay and 6 per cent. of coke-dust. The effect of the last-named material was insignificant, a fact proved by the circumstance, which the authors thought would be obvious, namely, that the first melting of the iron in making the aluminium alloy really constituted a blank experiment, by means of which the carbon absorbed from the crucible could be measured. The amount, it would be noted on reference to the analytical table, was steady at 0·02 per cent.

The PRESIDENT said that, in the absence of Professor Arnold and Mr. Knowles, he begged leave to move a cordial vote of thanks to them for their paper.

The vote of thanks having been carried by acclamation, the meeting then adjourned until Wednesday, May 12.

On reassembling, the following paper was read :—

## ON CHARGING OPEN-HEARTH FURNACES BY MACHINERY.

BY JEREMIAH HEAD, M.I.N.T.C.E., PAST PRESIDENT OF THE  
INSTITUTION OF MECHANICAL ENGINEERS.

THE gradual development during the last twenty-five years of the open-hearth process for the manufacture of steel, and the severe competition which has since arisen between different districts and countries, has compelled more and more attention to be paid to all expedients which promise to save labour, time, and other elements of cost.

*Materials Charged.*—Confining our attention for the moment to the acid process, which is that by which open-hearth steel is at present usually made in this country, we find that for every ton of steel produced in the shape of ingots, the following quantities of materials are introduced into the furnace:—

	Cwts.	Percentage of Charge.
Hæmatite pig iron . . . . .	16	66·7
Wrought scrap . . . . .	4	16·7
Ore (containing 50 per cent. Fe) . . . .	4	16·6
Total . . . . .	24	100·0

The 20 cwts. of pig iron and scrap lose by oxidation about 10 per cent. or 2 cwts. But the 4 cwts. of ore, containing as it does 2 cwts. of metallic iron, just replaces this loss, as it becomes reduced by the action of the metalloids associated with the pig.

*Acid and Basic.*—The ratio of iron-containing materials charged to the steel produced does not seem to differ materially, even though the relative proportions of pig, scrap, and ore may vary considerably.

The following table gives the average practice over the year 1896 at a works in America where there are several 15-ton furnaces, with both acid and basic linings. Basic additions and ferro-manganese are in no case included:—

	Acid Furnaces.		Basic Furnaces.	
	Weight Charged per Ton of Ingots.	Per Cent. of Charge.	Weight Charged per Ton of Ingots.	Per Cent. of Charge.
Pig iron . . . . .	Cwts. 6	27	Cwts. 11 $\frac{1}{2}$	51
Scrap . . . . .	15 $\frac{1}{2}$	67	10 $\frac{1}{2}$	45
Ore . . . . .	1 $\frac{1}{2}$	6	1	4
Total . . . . .	22 $\frac{1}{2}$	100	23 $\frac{1}{2}$	100

For the purposes of this paper I will assume that 24 cwts. of material must be introduced into the furnace, whether acid or basic, for every ton of ingots produced.

*Capacity of Furnaces.*—The capacity of modern open-hearth furnaces varies considerably. The tendency hitherto has been towards continual increase. Typical steelworks in the North of England have 30-ton, 40-ton, and 50-ton furnaces. Forty-ton furnaces may be taken as a fair average for a modern plant.

Such furnaces when in full working order make nine heats per week of 141 hours, that is from say 6 P.M. on Sunday night to say, 3 P.M. on the Saturday following. This gives  $\frac{141}{9} = 15\frac{1}{3}$  hours for each heat, including fettling and charging. The full weekly produce of such a furnace would be  $40 \times 9 = 360$  tons of ingots.

But furnaces cannot be relied on to work fully or continuously. There are various contingencies, but too well known to managers, which prevent this.

The actual production of an open-hearth plant varies from seven-eighths to three-quarters of its nominal capacity, and indeed is sometimes even less than that. Or, put in another way, from one-eighth to one-fourth of the furnaces comprised in any steel-melting plant are on the average always standing for repairs.

A 40-ton furnace in fair working order requires every 15 $\frac{1}{3}$  hours  $40 \text{ tons} \times 1.2 \text{ tons} (\text{or } 24 \text{ cwts.}) = 48$  tons of materials to be charged into it, and this occupies under present circumstances

(in addition to an hour for fettling) about  $3\frac{1}{2}$  hours, which is equivalent to  $\frac{48}{3.5} = 13.7$  tons per hour.\* To perform this, among other duties, three men are employed (on each shift), called the first, second, and third hands, and these three men employ a fourth to aid them in dealing with a furnace of the size mentioned. The total number of men employed on both shifts is thus eight per furnace.

*Picked men required.*—It is clear therefore that each of these four men handles on the average  $\frac{13.7}{4} = 3.4$  tons per hour for  $3\frac{1}{2}$  hours or about 12 tons in all, each charging shift he is at work, which is alternately four or five times per week. To some furnaces light swing cranes are attached, but these are only or mainly used for heavy castings, cobbles, and so forth. The pig, scrap, and ore has to be charged by hand, and that in face of a furnace radiating a considerable amount of heat. It is evident that to fulfil these requirements great physical and constitutional strength is necessary in all the men, besides technical skill, which, however, is exercised mainly by the first hand. They must therefore be picked men, and must be paid accordingly.

*Cost for Labour.*—In this country the labour needed for open-hearth steel-melting is paid by a tonnage rate on the ingots produced. The present rate is 1s. 10½d. per ton net. In a 40-ton furnace this amounts to—

$\frac{\text{£}}{\text{s.}} \quad \frac{\text{s.}}{\text{d.}}$	$\times 40 \text{ tons}$	$\frac{\text{£}}{\text{s.}} \quad \frac{\text{s.}}{\text{d.}}$	per full heat.
0    1    10½		3    15    0	
3    15    0	$\times 9 \text{ heats}$	33    15    0	per full week.

$33 \quad 15 \quad 0$	$= 4 \quad 4 \frac{1}{2}$	the average earned per man per full week.
8 men.		

The average earnings per man taken over the whole year are, however, less than this by one-eighth to one-quarter, as before explained.

These labour costs, which apply to the charging platform only, do not seem unreasonable under the conditions I have described.

*Saving of Time and Labour.*—It is to reduce the time required

\* A 40-ton furnace can be charged by hand in  $3\frac{1}{2}$  hours only by having two doors on the tapping side as well as three on the platform side. This is now customary in the North of England.

to charge a furnace, and to prevent the necessity of so much and such costly hand-labour, that charging machinery has been devised and brought to great perfection during the last few years in the United States. To this machinery I now propose to invite your attention.

*Original Charging Machine.*—Fig. 1 (Plate IX.) shows the first charging machine for open-hearth furnaces ever made. It was designed and erected just ten years ago at the works of the Otis Steel Co. of Cleveland, Ohio, by Mr. S. T. Wellman, then superintendent of the works, and is still in operation there.

It consists of a main carriage on four wheels, travelling longitudinally on overhead girders along and above the charging platform. On the carriage, and moving transversely to it, is a truck called the charger truck, having four wheels above and four below the cross girders of the main carriage. To the truck is attached an inverted hydraulic cylinder with piston and rod, to the crosshead of which a horizontal platform is fixed. The cross-head is guided by wheels travelling on strong guides depending from the carriage. As the piston is raised or lowered, so is the platform. The machineman or operator sits at the back end of the platform facing the furnace with his handles conveniently placed in front of him. The crosshead has in it a large horizontal hole at right angles to the furnace front, and through this passes a strong horizontal bar called the charging bar, which can be rotated or twisted by another inverted hydraulic cylinder on the platform acting on a rack and spur-wheel. The longitudinal motion of the main carriage is effected by a fixed steam-winch at the end of the charging platform. The charger truck, carrying with it the operator's platform and charging bar, is moved toward or from the furnace door by two horizontal cylinders fixed to the main carriage.

The materials are brought up to the charging platform on bogies, called charging bogies, running on a subsidiary 2-feet gauge railway, which connects it with the stock heaps and with the full-gauge input sidings, and constitutes a complete system, with miniature locomotives, turn-tables, hydraulic lifts, and so forth. Placed upon and across each charging bogie are three or more charging boxes (or scoops), into which is loaded, at the stock heaps or input sidings, the pig iron (each pig being broken

in two pieces), the scrap, and the ore. Each box contains approximately a ton of material.

The ends of the boxes, which, on arrival at the charging platform, are next to the machine, are steel castings formed into sockets. The end of the charging bar, which is made to fit, is brought over and dropped successively into these, and (in the original machine) temporarily secured by a wedge-shaped key driven in by a boy. The operator is then able, by means of the lifting, cross-traversing, and twisting cylinders, to introduce the box and its charge into the furnace, empty and withdraw it, and return it to the bogie; and the boy having knocked out the key, he repeats the process with the next one.

*Defects of Original Machine.*—Although this machine has worked fairly well from the first, and has effected a considerable saving compared with charging by hand, it is evidently far from perfect. The hydraulic movements are too slow, and there is loss of power when they take place with less than maximum resistance. The boy needed to fix the boxes, and the isolated steam-winches, with its attendant, ought clearly to be dispensed with. The constant supply of high-pressure water to a machine travelling longitudinally over a considerable distance is attended with difficulty, and india-rubber pressure-pipe, if used near hot furnaces, is difficult and costly to maintain. It is further evident to the eye of a mechanic that the original charging machine is deficient in strength and rigidity, and is suitable only for very light loads.

*The Thurlow Machine.*—For the reasons given, machinery for charging open-hearth furnaces attained but limited success, until at length electricity became available as a motive-power. In May 1894, Mr. Wellman constructed at Thurlow, Pennsylvania, a charging machine in which all the movements were electrical, except locking the charging bar to the boxes. This apparatus travelled longitudinally on rails at the floor-level. The floor of the main carriage was divided into three oblong sections, the two-outer ones being fixed, and the centre one sliding towards and from the furnace. This section carried the charging bar, the motor and gear for sliding it, the motor and gear for twisting it, and the hand-gear for locking it to the charging boxes. The motors and gear for giving longitudinal movement to the main

carriage and for raising or lowering the front end of the sliding section, were placed on the left side fixed section, whilst the operator with the rheostats and current controllers sat on the right side fixed section.

*Defects of the Thurlow Machine.*—The apparatus was perfectly successful so far as its performance was concerned, but it had certain obvious defects. For instance, the main frame covered a floor width of 19 feet instead of 14 feet, which alone is necessary in the latest design. The weight of the operator and his platform with the controlling gear were not utilised to counterbalance the charging box and its load. The operator was not immediately behind and opposite to the charging door, and therefore could not always see what he was doing. And lastly, the main carriage and its fittings were not massive enough to form a sufficient base for carrying heavy loads in the boxes when the charging bar was at its farthest forward position.

*The Newest Type of Electric Machine.*—These defects have now all been remedied. Figs. 2, 3, and 4 (Plates X.-XII.), and also the model upon the table, represent a machine of the newest type, which has just been made by Mr. Wellman for the Otis Steel Co., so that that Company now possesses the most recent as well as the oldest and two intermediate examples of charging machines.

Fig. 2 shows a cross section of a furnace, the charging bogie with a charging box upon it, and the charging machine itself.

Fig. 3 shows the same in plan, and Fig. 4 in back elevation.

It will be seen that the apparatus has much in common with those which preceded it. It is, however, more substantial, whilst at the same time it is simpler and more compact. The main carriage is 5 feet narrower from back to front than in the case of the Thurlow machine, which is a great advantage in that less floor room needs to be kept clear. Stability is maintained by extending it 3 feet longitudinally, an addition which interferes with nothing. At the four corners of the main carriage, box columns are erected which are surmounted by a framework consisting in the main of a pair of channel section beams fixed transversely to the columns and projecting forward beyond the main carriage, almost as far as the furnace front. The channel beams carry rails on which runs on four wheels the charger truck. Above the wheels on either side are steel angles which

serve the purpose of guard rails in case the truck should tip up behind.

Downwards from the charger truck projects a strong bracket, ending in double-eye bearings, which carry a trunnion sleeve. Into this sleeve is threaded and secured with a back collar the charging bar. On the after end of the latter is carried the operator's platform, the tail end of which is connected by two rods with the pins of two cranks, keyed symmetrically to a shaft running across the charger truck frame at its rear end.

A motor carried on the truck is connected by gear with this shaft. By switching on the current the operator can rotate the crank shaft in either direction, and so move the charging bar up or down like a heavy gun in its trunnion bearings. As the motion is of the "all-round" type, no harm can come from overrunning. On the charger truck is also mounted a motor and gear for moving it and the charging bar, and all connected therewith towards or from the furnace by operating on the front axle and wheels.

*Locking Gear.*—In the most recent machines the rather complicated method adopted in the Thurlow example for locking the charging bar to the boxes has been superseded by a very simple device. The charging bar is hollow throughout its length, and the interior is occupied by a steel rod connected with a lever on the operator's platform. When the front end of the charging bar has been lowered into the socket of the box, the operator, in order to lock them together, pushes forward the locking bar by means of the lever, until the front end projects into a recess provided for that purpose in the socket of the box. A reversal of the process releases the box. The front portion of the charging bar is separate from, but keyed to the back portion, so as to facilitate renewal in case of wear or accident.

The motor and gear for moving the machine longitudinally is upon the main carriage, and, as in the case of the charger truck, acts on one axle only. The motor and gear for twisting the charging bar is upon the operator's platform, as are also the controllers and switches for all the motors. The accumulation of these weights in that position balances to some extent the weights lifted by the charging bar. It will be noticed that in this machine, as in the original one at the Otis Steel Works, the

operator is always opposite to his work, and moves to and from the furnace with the charging bar and box. He is therefore able to see into the interior of the furnace when depositing materials therein, and at other times remain in a cool place.

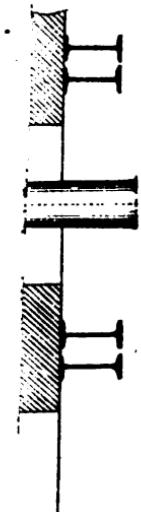
*Electric Arrangements.*—The motors for producing the requisite movements are each 25-horse power, except that on the operator's platform for twisting the charging bar, which is only  $3\frac{1}{2}$ -horse power. But as the maximum effort is seldom required in any of the movements, and as they are successive and not concurrent, 25-horse power may be considered the maximum used by them all at any one time. The power continuously used does not in all probability exceed an average of 10-horse power whilst the machine is at work. The electric current is brought from the central generating station, a department with which large steel-works in the States are now almost always provided. The current, which is brought by a single pair of conductors running overhead along the charging platform, is conveyed to the operator's platform by sliding contacts, to be there distributed to the various motors. The new high-framed machine has a great advantage over the old low-framed ones, in that it admits of the necessarily bare conductors and contacts being kept high up and well out of the way of the traffic on the floor. The power at the central station may and should be generated by economical engines under favourable conditions. Little pressure is lost in transit, and no current is taken by the machine except when at work, and then only in proportion to the work actually done. The motors are of a simple type, encased in iron, like those so common in America for use under electric street cars. The current is a continuous one, and the voltage used is 220 to 250.

*Forty-eight Tons Charged in an Hour.*—The charging boxes are 6 feet long by 2 feet broad and  $1\frac{1}{4}$  feet deep, which gives a capacity of 21 cubic feet. This is sufficient to contain a ton of ore or scrap and more than a ton of pig iron. Except when heavy castings and cobbles are to be dealt with, a ton is a convenient average load for a charging box, and three or four tons for a charging bogie, according to whether it is made to carry three or four boxes. If the boxes are properly loaded, the machine will pick up and empty one every minute, which is equivalent to dealing with an entire charge of forty-eight tons in forty-eight minutes. Allow-





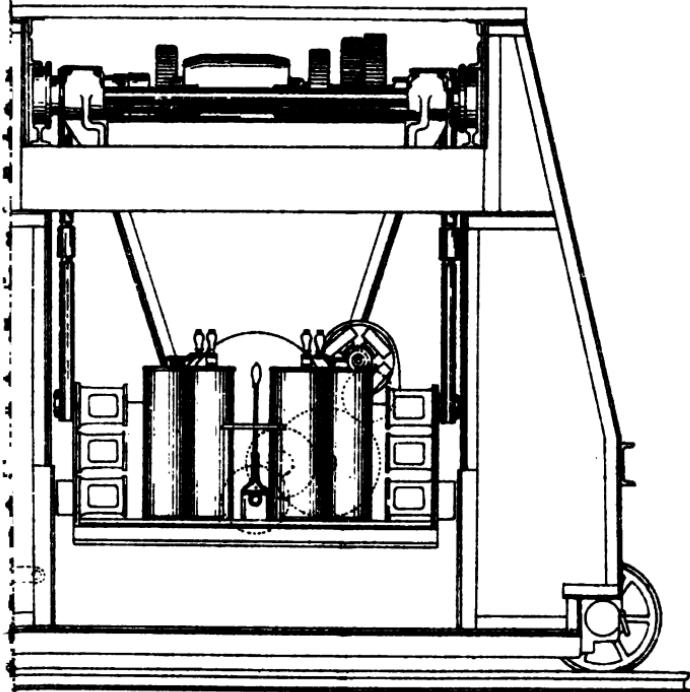
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ELCTRIC OPEN HEARTH CHARGING MACHINE

1897



BACK ELEVATION.

Fig. 4.



ing twelve minutes for contingencies, a charge would occupy one hour instead of  $3\frac{1}{2}$  hours, which is an ordinary time required for charging a 40-ton furnace, exclusive, say, of one hour for fettling. This would be required in either case.

Thus a saving of  $2\frac{1}{2}$  hours per charge is effected by the machine.

*Output Increased 11 per Cent.*—The time gained per week by using machine against hand labour may be expected to be at least  $2\frac{1}{2}$  hours  $\times$  9 heats =  $22\frac{1}{2}$  hours, which is more than sufficient for an extra heat, or an increase in the total output of one-ninth, or 11 per cent.

*Labour Saving.*—The saving to be effected by using electrical charging machinery is not one of time only. I have shown that at present 8 picked men (2 shifts) are employed (in British steelworks) at each 40-ton furnace, and that these men handle among them 48 tons  $\times$  9 heats = 432 tons of material every full week, the handling being done in 9 heats  $\times 3\frac{1}{2}$  hours =  $31\frac{1}{2}$  hours.

This is equal to  $\frac{432 \text{ tons}}{31.5 \text{ hours}} = 13.7 \text{ tons per hour while charging,}$

or  $\frac{13.7 \text{ hours}}{4 \text{ men}} = 3.4 \text{ tons per hour per man for a period of}$

$3.4 \times \frac{9 \text{ heats}}{2 \text{ shifts}} = 15.3 \text{ hours per week.}$  Now where the machine is employed, the whole of this heavy labour is done by it, and the material need never be touched by the men at all unless something goes wrong, or unless it be necessary at any time to adjust the position of any portion of the charge in the furnace. It is clear, therefore, that the machine is a labour-saving as well as a time-saving appliance.

*Economies effected in America.*—On the next page I give an estimate made from information supplied by Mr. Wellman of the saving in cost of labour by the use of machine-charging as against hand-charging in two 20 to 30-ton furnaces in the United States. It will be seen therefrom that in that country, even when working with fewer and smaller furnaces than we are accustomed to here, they are able to reduce the number of men required by one half, and the weekly labour cost to the same extent.

## ESTIMATE OF SAVING OF LABOUR BY THE USE IN THE UNITED STATES OF MACHINE- OVER HAND-CHARGING.

*Cost of Labour in Operating by Hand Two 20 to 30-Ton Furnaces.*

1	Melter, wages per week . . . . .	\$30·00
2	First helpers (22½ cents per hour each) . . . . .	32·40
2	Second helpers (15 cents per hour each) . . . . .	21·60
6	Stockers (13½ cents per hour each) . . . . .	58·32
1	Door-boy . . . . .	5·40
<u>12</u>	Cost of labour in one week, single turn . . . . .	<u>\$147·72</u>
	Multiply for double turn . . . . .	2
		\$295·44

\$295·44 = 2s. 6d. per ton  
at 500 tons per week.

Total Number of Men Employed Hand-Charging (including Stockers).		
	Per Two Furnaces.	Per One Furnace.
Per turn . . . . .	12	6
Per double turn . . . . .	24	12

*With Charging Machine.*

1	Melter, wages per week . . . . .	\$30·00
1	First helper (22½ cents per hour) . . . . .	16·20
2	Yard loaders (12 cents per hour each) . . . . .	14·40
1	Machine operator (20 cents per hour) . . . . .	15·40
1	Boy . . . . .	5·40
<u>6</u>	Cost of labour in one week, single turn . . . . .	<u>\$81·40</u>
	Multiply for double turn . . . . .	2
		\$162·80
	Net saving labour in one week . . . . .	
	Net saving labour in forty weeks . . . . .	
	Less 10 per cent. depreciation and repairs . . . . .	\$750·00
	Less 6 per cent. interest on cost of machine . . . . .	450·00
		\$1,200·00
	Net saving in forty weeks . . . . .	

\$162·80 = 1s. 3d. per ton  
\$132·64 at 550 tons per  
40 week.

\$5,305·60

1,200·00

\$4,105·60 = £844

Total Number of Men Employed Machine-Charging (including Yard Loaders).		
	Per Two Furnaces.	Per One Furnace.
Per turn . . . . .	6	3
Per double turn . . . . .	12	6

Nothing is deducted for wear of cars and boxes, as it is not estimated that this will be any more than that on the barrows, tools, and cars used in hand-work. Ten heats per week is assumed with hand-charging and eleven with machine-charging. The machine and its operator are charged to two small furnaces, whereas they could easily work six large ones.

Taking forty working weeks only as a year, and allowing 16 per cent. on the cost of the machine for interest, depreciation, and repairs, the savings by each machine appear to be £844 per annum. This estimate takes no account of the gain in lower establishment charges by increased output. If we take the output of the two furnaces at 500 tons per week with hand-charging, and 550 with machine-charging, we shall find that by the former method the labour costs 2s. 6d. per ton of ingots, and by the latter only 1s. 3d. per ton.

The use of the machine, therefore, converts the advantage we have hitherto had in England over our American competitors in cost of labour to a similar advantage to them over us. In America lessened labour is generally synonymous with lessened cost for labour. It is not always so here.

*Two Machines to Six Furnaces.*—If the machine will charge one furnace in an hour, it is obvious that it will charge at least a dozen in the  $15\frac{1}{2}$  hours, which we have taken as the average duration of the heats (including charging and fettling) of a 40-ton furnace. But in practice this cannot be done, because the charges cannot be relied to follow one another with precise regularity. One machine will, however, easily serve six furnaces. But bearing in mind the possibility of a breakdown, and the serious loss which might result therefrom, it is recommended that they should be used in pairs—that is, one to each six furnaces at work, and one in reserve.\* It will be noticed that the operator in the United States is paid at the rate of 45s. per week.

*Supply of Materials.*—The effectual employment of a charging machine is dependent on the materials being brought in charging boxes on specially constructed bogies to the charging platform, between the machine and the furnace front. The best arrangement is that shown in the diagrams, the full bogies arriving in

\* There is no doubt that eight or more 40-ton furnaces might safely be worked with two machines.

succession at one end of the platform, and the empties leaving at the other end. They are supposed to have been loaded at the stock heaps or input sidings, and to be returned straightway thereto. Charging platforms where machine-charging is in operation are free from stocks of materials, standing waggons, and other impediments to a remarkable degree, and their coolness and cleanliness is at once remarked by those accustomed to hand-charging.

*Narrow-Gauge Bogie Line.*—The charging bogies may reach the platform level by an incline fitted with a continuous creeper, which is an excellent device, and they may descend the same way, or be pushed up by a small locomotive, or be raised by lifts. Where, as in some British works, it is difficult to make these arrangements, the materials may continue, as previously, to arrive at the back of the platform and be there loaded into the charging boxes on bogies. These, by aid of a few small turntables (such as are common on pit-banks at collieries), can easily be pushed round by hand to a position where the charging bar can operate upon them. But the arrangement shown is best. The charging machine itself is frequently used as a locomotive to push away empties and bring forward full bogies.

*Doors Lifted by Power.*—In the United States the furnace doors are usually lifted by hydraulic or pneumatic power, operated by a boy in a pulpit at the back of the platform. One boy works the doors for two furnaces. This seems better than the plan of lifting them by levers attached to the furnaces, which is usual here.

*Charging Castings and Cobbles.*—For loading broken castings and heavy cobbles such as waster ingots, the machine may be used with great advantage. In that case the cobble would arrive on a charging bogie in the usual way, but the charging boxes would be dispensed with, and a broad fork having a socket shank would have been placed upon the bogie before the cobble was loaded up. The machine would lift the fork with the cobble on it and introduce it into the furnace just as if it were ordinary material.

In case the weight of the casting or cobble were sufficient to over-balance the machine, the stability of the latter might be largely increased by depositing pig iron into the back box columns of the framework.

*All Laborious Work done by Machine.*—Even if it were not found possible here to lessen the labour cost per ton of steel produced, it is clear that the use of a charging machine must make a manager less dependent upon men selected largely for their physical strength. The machine would do all the hard labour and the men would be reserved for more strictly human work.

*Where Machine Charging is in Operation.*—Charging machines are now in regular operation at several works in the United States. These include the Otis Steel Works, Cleveland, Ohio; the Homestead Works of the Carnegie Company at Pittsburg; the Illinois Steel Works, S. Chicago; the Cambria Iron Works, Johnstown, Pennsylvania.

In Germany there are two or three examples, but they are believed to be all of the Thurlow type, or closely allied thereto. In this country none are yet in operation, but two have been ordered by the Llanelly Steel Company of Llanelly, and these will probably be at work in the course of the autumn.

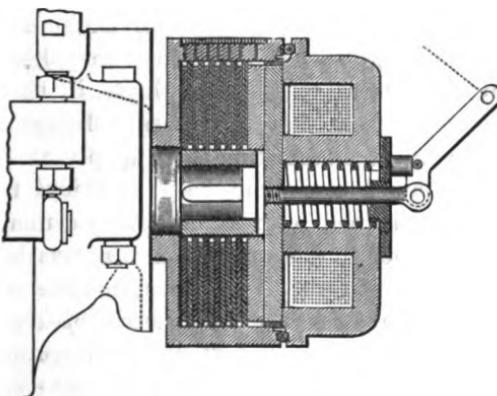
*Conclusion.*—In conclusion, I desire to tender my thanks to Mr. S. J. Wellman, and his brother, Mr. C. S. Wellman, and their partner, Mr. Seaver, for much of the information I have been able to put before you; also to the Carnegie Company for allowing me see the machines at their Homestead Works; also to Mr. G. Bartol, Superintendent of the Otis Steel Works, and to my son and partner, Mr. A. P. Head, for preparing the illustrations, and otherwise affording me valuable assistance.

*DISCUSSION.*

Mr. A. P. HEAD wished to offer a few brief remarks, especially on the electrical part of the machine. He thought that what must strike every mechanical engineer was the successful way in which motors had been adopted instead of the usual hydraulic rams. It might naturally be supposed that the very delicate, gingerly motions of the machine would be better accomplished by the slow, steady, rectilinear motion of a ram than by the rapid rotary motion of an armature. He might emphasise that high speed by saying that if the front end of the charging-bar were moved from the lowest to the highest position through a distance of only 20 inches, the armature of the motor would have to perform no less than forty revolutions; while to rotate the charging-bar once, in order to empty a box, the armature of the motor which drove it would turn forty-eight times. Yet, in spite of those high velocities, by having the armatures very light and with a minimum of inertia, the various motions could be stopped, started, and reversed very quickly, and the whole machine could be handled with as much nicety and precision as if it were hydraulic.

All the motors were series-wound, the object being to get a strong starting torque rather than uniformity of speed. All the motions, with one exception, were stable—that was, they would stop where they were put without running back. The one exception was the rising and falling motion. If the weight of the front end of the bar more than counterbalanced the platform, the platform would tend to rise to its highest position, and, on the contrary, if the front end had no load, the platform would tend to fall. It was, therefore, necessary to provide a brake. This was shown in section in the accompanying drawing. The object of the brake was, that when the current was turned on to the motor the gear should be automatically released, and when the current was turned off the gear was locked. The diagram showed in outline one end of the motor and one end of the armature shaft. The other end, which was not shown, carried the pinion. On the shaft was keyed a square cast iron bush,

which drove seven brass discs. These were fitted loosely enough to be moved sideways. Alternating with these were seven mild steel discs, which were prevented from revolving by grooves in the periphery which fitted projections on the inner surface of the outer case, which was itself bolted to the frame. Under ordinary circumstances a strong spiral spring kept the discs squeezed up sideways, and the large amount of contact surface between the revolving and fixed discs prevented the armature from rotating and locked the whole gear. When the operator wished to start the motor, the current was made to pass on its way through the coil, shown in section, and in doing so it converted the mild steel brake-cover into a powerful magnet, which



attracted the outermost disc against the force of the spring, thus relieving the pressure and enabling the motor to start. Similarly, when the current was cut off, the discs were squeezed up by the spring and the gear stopped dead. Thus, whenever the front end of the charging-bar was not moving up and down, it was absolutely fixed and rigid.

Mr. JAMES RILEY, Vice-President, said that any one who had witnessed the operations of the charging of a large melting-furnace must have felt some degree of sympathy for the men engaged in that operation. In the earliest days, when furnaces held only 6 or 8 tons, that feeling came over him very frequently, and he had no doubt that all who were engaged in Siemens steelworks

had, like himself, devoted a good deal of thought to the question of how that severe manual labour could be avoided. In the early days, and frequently since, he had given attention to the subject, but almost invariably he arrived at the conclusion that there was no economy in the use of machines as compared with the cost of manual labour for that purpose. But undoubtedly now-a-days, when they had to do with such heavy charges, the whole conditions were altered, and he thought most of them would feel that, given a thoroughly good and trustworthy machine which would do the work expeditiously and well, it must be of great service to those who possessed it.

He had considered the earlier machines made by Mr. Wellman, but he was bound to say he had the impression that they were cumbersome, and that although they might do in America, where there were large spaces, and where they had also to pay very high rates of wages to their employés, in this country, at all events, he did not see that there was sufficient attraction in them to warrant his recommending their adoption.

The latest machine, which had been exhibited to them that morning, undoubtedly had a great deal to recommend it. He did not know whether it was due to his conservatism or not, or whether it was common to all of them, but the one thing he should hesitate about was the application of electricity. It seemed to him to involve a good many considerations. In the first place, if they had not—as was almost universally the case in this country—those large electric installations, that was a cost which had to be faced before those machines could be put into operation. If they did exist, and there was a skilled man in charge of the electrical apparatus, then, of course, that objection was removed. Then came the thought of the position in the works which the machine occupied; the trouble which might arise from dust, or other causes with which they were all acquainted, which might interfere with its successful working. At all events, he did not think that this country had yet got such a strong confidence in the use of electrical apparatus in steelworks as that they might venture readily, at all events without full consideration, to expend the large sum of money necessary for an installation, not of one machine, but, in large works, of two, or three, or four of those machines. They would

like to know and see more of the actual working of that electrical apparatus. Those were the thoughts that had passed through his mind in the course of reading the paper, for he had not seen the machine; but he should be tempted, notwithstanding his doubts on the few small points he had mentioned, to venture to make use of that machine in connection with very large furnaces.

Mr. LAUDER (Edgar-Thomson Steelworks, Pittsburgh) was not at all prepared to go into any details about the machine, but he was glad of the chance of speaking about it for a minute or two. With regard to the objections which had been urged, he could assure them as a fact that there were no objections whatever to the use of electricity in steelworks. Like a great many, he was very much opposed to the use of electricity so extensively when it was first proposed, but he had become a complete convert. It was said that facts spoke, and the facts that had caused him to form this opinion had been the financial result. They had made wonderful reductions in cost since they began using electricity so extensively as they had done. The writer of the paper had shown all the details of the machine so accurately and so nicely that he really had nothing further to add in that respect. He could simply tell them that his firm were entirely satisfied with the working of the machine, and they thought Mr. Wellman was entitled to a great deal of credit for the manner in which he had designed and put it into operation.

Mr. W. R. STIRLING (Illinois Steelworks, Chicago) did not think he could add anything to what Mr. Head had said in his paper, for he had covered the ground very fully, and he was unable to go further into the matter in detail, for the reason that the Illinois Steel Company never had any hand-charging for their open-hearth plant; they considered it impossible, or at least unadvisable, to contemplate going into a business of that kind without automatic means of charging. He knew that the machines gave great satisfaction, and there was no fault to be found regarding the use of electricity, which was increasing more and more every day in all the large establishments.

Mr. E. WINDSOR RICHARDS, Past-President, said that through

the courtesy of Mr. Lauder and Mr. Carnegie, he had had the pleasure of accompanying them to Homestead a few years ago, and he had seen some of those machines charging the basic furnaces. He felt envious of the whole arrangement. The large space of ground mentioned by Mr. Riley, that was impossible here, made one wish that they could pull down the whole works at Bolckow's and start afresh. He was bound to say that the machine worked remarkably well. They were charging very large ingots, perhaps not, for one reason or another, quite right into the furnace, but in nearly as easy a manner as it was done just now by Mr. Archibald Head in his demonstration of the model exhibited. The main question was, after all, was there any great saving in it? He was inclined to believe that there was. There must be a great deal less wear and tear on the furnace and in the cooling down, which was a very important matter. He supposed the roof of a Siemens furnace of, say, 40 tons, would be about as troublesome a thing in a steel-works as one could well imagine. Mr. Riley was of course much more competent to speak on that point than he was. On the whole, he should say it was a most desirable thing, and if any one could, with the old existing plants in this country, adopt something like this, which was really a simple machine —there was nothing very complicated about it—he thought it would be very advantageous that they should do so. They were all surprised at the enormous outputs in America, whether from the Siemens furnace or from the blast-furnace, or the rolling-mill, or other plant. There must be some reason for this; it was that they were so quick to adopt any new device. In Great Britain, on the other hand, there was always hesitation, owing to fear of the machine breaking down and stopping the works. British manufacturers must not be so slow in the future as they had been in the past in taking up these improvements.

Mr. GEORGE AINSWORTH was afraid he could not add very much to the discussion. There was no doubt that every one connected with the Siemens furnace would be only too glad if something could be brought before them in the shape of a practicable machine for saving the laborious charging which now had to be gone through. He was inclined to think, however,

that they sometimes magnified the saving to be effected, because all of them knew that whilst they were charging a furnace it was not altogether time lost. A certain amount of melting during this period was always going on, and the consequent gain therefore by shortening the operation was not altogether so great as it at first sight appeared to be. At the same time there was no doubt that an important saving might be effected by some machine.

The only point which struck him, so far as he had seen the working of the model of the machine before them, was that he did not quite see how they could lay the material round the furnace in the way it was done by hand, and which was generally supposed to be absolutely necessary. He was not prepared to say whether that was so or not; but it was a belief amongst them that they must have some means of carefully laying the pig iron round the sides of the furnace, to allow them to dispose properly of their scrap, and prevent excessive wear and tear of the hearth of the furnace. Of course what struck them on the face of it was that no charging machine such as that ought to be necessary. The simplest charging machine they could possibly have would be a ladle with fluid metal. Unfortunately, at that stage they had not yet arrived.

Mr. F. W. PAUL said he thought Mr. Ainsworth had fairly well covered the points which he had contemplated speaking about. As regarded any mechanical difficulties in the working of the machine, he thought the fact of its being in daily operation in America would largely discount any fears that they might have on that point. With respect to its replacing of men, he did not feel very sanguine that such an arrangement would cheapen the total cost of labour per ton of ingots in this country, for in the operation of a 40-ton furnace, such as tapping, fettling, and feeding ore whilst the charge was on the boil, three men were required; but he was strongly of opinion that the high-rated first hand ought to be replaced by cheaper labour for charging irrespective of a charging-machine, because the skill of a first hand consisted in safely maintaining the furnace at a high temperature and in properly working the charge. It was therefore unreasonable that this high-rated skilled man should be employed in the

purely manual work of charging. He was also of opinion that it was desirable to cover the banks with pig iron, so that the oxide of iron (which formed whilst melting the steel scrap) did not come in contact with the acid banks of the furnace, which would necessitate longer time in repairing and fettling the furnace. In America basic furnaces were chiefly used, and probably that difficulty had not been experienced there in connection with the charging-machine, but it was a point worthy of consideration in this country, where acid bottoms were more exclusively used.

Mr. ENOCH JAMES had given some attention to the matter, and having had some experience with electrical cranes in melting-shops, he was able to assure Mr. Riley that electrical work was not attended with those difficulties which he assumed. He had had the notion of constructing a charging-machine himself, and he thought that he had attempted more than had been attempted here. He conceived the idea of bringing the pig iron from the blast-furnace to the charging-tool without a man touching it. As some of them were aware, at the Dowlais Cardiff Works, with which he was connected until recently, the pig iron was broken by machinery, and was delivered by means of a shoot into trucks. That shoot would be very suitable to deliver the pig iron into boxes. He contemplated bringing the boxes *there*, and instead of having separate boxes to go into the furnace, he thought of getting one box only with a sliding bottom, thinking possibly that the tipping over of a ton of pig iron would damage the bottom of the furnace a great deal more than withdrawing the bottom and letting the charge of the pig iron just find its level in the furnace. He thought a great deal remained to be done in that particular direction, and no one need have any apprehension as to making use of electrical work in connection with steelmaking. He might add that having arrived at the same conclusion as Mr. Ainsworth with regard to fluid metal, he had left the mechanical charger in abeyance and had proceeded to use molten metal. That was done by means of a 30-ton overhead travelling crane, driven by electric power, lifting the ladle which conveyed the molten iron from the blast-furnaces and placing it in front of the melting-furnace. The ladle was tilted by worm-wheel gearing, and the

metal flowed over a short trough into the furnace. During the brief period these trials were being made, upwards of 2000 tons of molten pig iron were charged most successfully in this way. He had satisfied himself as to the great advantages to be derived from this method of working.

Mr. J. W. SPENCER said he did not know that he could add anything to the discussion, but should like to say he did not think steel manufacturers were quite so bad as painted by Mr. Windsor Richards, in not availing themselves of new inventions that came forward. He did not think they were always in a position to do so. There were at least two factors to contend with—one that in most cases their works were laid down some time ago, and it was not always possible to adapt all these improvements to existing plant, as in the case before us ; and secondly, few could afford to reconstruct in a country where the supply was largely in advance of demand. Besides, they had another factor which he thought would probably interfere with the adaptation of this machine in numbers to their furnaces, and that was the consent of the men. They had not in the past got the returns from the men they should have for the capital laid down for labour-saving. Whether they were to be more fortunate in adopting an installation like this he did not know, but if they did, where it could be used it might be a very valuable addition to the appliances they had for steelmaking.

Sir EDWARD CARBUTT, Bart., thought that, as a mechanical contrivance, Mr. Head's machine was very good indeed. They were very much obliged to him for bringing the paper before them. He rose more to emphasise what had been said by their past President, Mr. Windsor Richards. He thought there was no doubt that in this country manufacturers were a little too conservative, and considering that they formed part of a country that had the money, and that money was so cheap that people did not know what to do with it, they need not be quite so frightened as they had been. Mr. Windsor Richards had done a large amount of good to his country in calling attention some time ago to what had been done in America ; and by his speech that morning he had earned some credit in the same direction, because it was a great

pity to be frightened at going ahead because they had old machinery, and did not want to spend the money. If they were going to fight a battle, it was only by spending money that they could fight it successfully. He wanted to call attention to one point. It struck him that Mr. Head did not take sufficient credit for what he (Sir Edward Carbutt) conceived would be an advantage—that was, that the door of the furnace would only be opened a third of the time that it was open if they were charging by hand. They all knew that a furnace was getting pulled to pieces throughout when it was hot and they had got the furnace-door open; and he believed the less wear and tear in having the door open one hour instead of three and a half hours would very soon pay for a good deal of extra machinery.

Mr. DAVID EVANS, Member of Council, said they were greatly indebted to the author for his valuable paper, and for bringing the Wellman charging-machine before their notice. They all knew the laborious work the men had in charging the Siemens furnaces. When he (Mr. Evans) went to the United States in the autumn of 1895, he visited the Carnegie Works and also the Chicago Works, where they had 50-ton furnaces. A Wellman's machine was working there, and he was very much struck with the rapidity and the ease with which it did its work. He saw no difficulty there with reference to what Mr. Ainsworth spoke about as to placing the charge and spreading it properly over the furnace-hearth. They did it without any difficulty, and he was very much surprised at the enormous quantity that they were turning out per furnace. He had thought a great deal of adopting it, but the present arrangements of the plant at Eston would not admit of its ready adoption, but at the same time they were drawing out a scheme which he hoped would overcome the difficulty. As Mr. Riley and Mr. Windsor Richards said, they did not in old works always have plenty of room to enable them to put down further appliances, but he had such faith in it that he strongly recommended Mr. Trubshaw (who came to see him when he was making a tour of the various works in the country) to adopt this apparatus in the new works which he was putting down.

Mr. ERNEST TRUBSHAW said that, when he was at Middlesbrough last autumn, Mr. David Evans had been good enough to suggest that his firm should go in for mechanical charging at the Siemens furnaces at their proposed new steelworks at Llanelly, and that in laying out the works they should provide ample room for such a machine as that described in Mr. Head's paper. He need only say that he and his colleagues had fully considered the matter, and after having seen a similar machine working satisfactorily in Germany, they had decided to adopt it.

Mr. J. MAYBERY said he had been pleased to hear the discussion which had taken place. His company had ordered two of the machines, and he did not think that they had gone far wrong in so doing.

Mr. RAVENSHAW said that, as an electrical engineer, he should like to say a few words about reliance on electrical machinery of this kind. He had principally had to do with it in coal-mines and engineering works generally, and he had always found that, for electrical cranes, lifts, and hauling engines and pumping engines in mines, the use of electricity was most satisfactory. There was an immense number of electrical machines running in coal-mines at the present time under very bad conditions indeed. The wet and the dust were of course injurious to the machines if they were not properly enclosed; but they could be entirely enclosed, and when that was done they ran for years practically without any trouble at all. He had not had any experience in steel-works themselves, but he had the honour of describing a large electrical crane before the Institution of Civil Engineers a few weeks ago, and that crane was working in Woolwich Arsenal, where the steel tubes were annealed, the fumes and dirt being very considerable, and there had been no difficulty whatever in the electrical arrangements.

Mr. JEREMIAH HEAD, in reply, said he had not a very difficult task to perform, because in many cases the objections of some members had been answered by others. He was much obliged for the kind reception which they had given to his paper, and for the lenient tone in which they had discussed it. Mr. Riley

was wise in refraining from recommending the earlier machines, which were actuated by hydraulic power, for the reasons pointed out in the paper. Indeed, it could not be said to have attained real success until electricity was adopted as the motive power. Mr. Riley hesitated as to the use of electricity in such a machine as this. He need not attempt to remove Mr. Riley's doubts, because all which it was necessary to say on that point had already been so well said by Mr. Lauder and Mr. Stirling. They had had considerable experience of the machine, and other electrically driven machinery, and they were satisfied that Mr. Riley would presently change his mind. He (Mr. Head) had seen so much of the successful application of electricity for power purposes in the States and elsewhere, that he had long since ceased to regard it as a matter for hesitation. In fact, in this country there was no doubt that we were behind the times in the use of electricity, both for lighting and power purposes, as compared with our Transatlantic friends. Mr. Windsor Richards had remarked that as a nation we were apt to be too conservative, and that we were slower than our American cousins in the adoption of new ideas. There was no doubt that that was the case. The principal cure for that excess of conservatism was, he thought, to travel more.

If we only went abroad more, and saw what our competitors were doing—and he was sure they were always glad to see us—if we only did that to the same extent that Americans visited us, and inquired into what we were doing, he was quite sure that we should acquire some of their more go-ahead tendencies, and that would be to our advantage. The chief opposers of improved methods were generally those who had not taken the trouble to make themselves acquainted with them. It was impossible in these days to keep to the front without maintaining a constant acquaintance with all improvements in our own line of business wherever made. Mr. Ainsworth's difficulty, as to disposal of the charge inside the furnace, had been answered by Mr. David Evans, who, after having seen the machine in operation in the States, was satisfied that there was in practice no trouble at all of that nature. As to charging with ladles full of molten metal, that was a plan eminently suitable for the Bessemer process, which dealt with pig iron only; that is,

provided an intermediate desulphurising mixer was used. But open-hearth furnaces were not fed with pig iron only, but also with ore and scrap. As he had shown, the pig iron was sometimes only 27 per cent. of the entire charge. The question would arise how the other materials were to be dealt with. The 67 per cent. of scrap could not well be melted except in the furnace itself. Then, again, if the materials were brought in a molten state, their composition would have to be guessed at, more or less, and the result would be less under control. Charging with molten metal both in the steel-melting and the puddling furnace had been tried over and over again during the last thirty years, but so far without any marked success. He had no doubt whatever that what Mr. Paul and the President had said as regards labour was well worthy of attention. At each furnace there must be one man of skill and experience, and they must expect to pay him well. If his time was not fully occupied, as it certainly would not be by a single furnace, there was no reason whatever why he should not attend to two, three, or four furnaces. In fact, he ought to rank as a foreman rather than as a workman.

The use of the machine would certainly help to enable them to make such an arrangement. There was no sense in making a highly-skilled and highly-paid man do ordinary labour, such as putting pig iron into a furnace. It had been said by Mr. Spencer and others that in old works it was not easy to make improvements involving structural changes. That was so; but at the same time they must remember that Nature, in its economic laws, as well as other laws, was inexorable, and that if we were to retain our position in the face of the competition of the whole world, we must keep up to date whether we liked it or not. The fittest would always survive, and the weakest always go to the wall, however hard it might seem. He thought Sir Edward Carbutt's point, namely, that by means of this machine they would minimise the time during which the doors were open, was a very important one in preserving the life of the furnace. Mr. Trubshaw and Mr. Maybery had given the very best proof they possibly could of their belief in the machine by having actually ordered two, which were now under construction. They had the distinction of being the first in this country to adopt it.

1897.—i.

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The PRESIDENT said he rather agreed with some of the remarks which had fallen from Mr. Windsor-Richards as to their slowness of adopting new improvements. But there was another point that sometimes, perhaps, was at the root of the difficulty, namely, that the iron and steel trades generally were not so prosperous as to encourage them to go in for expenditure that they otherwise would do. There was another point to which he wished to call special attention to, and that was, Why was it that on the Continent furnaces of about 15 tons were charged and drawn so much oftener than we could get them drawn in this country? He knew as a fact that furnaces working with about 60 per cent. of scrap and the remainder of pig iron were making five heats in twenty-four hours, whereas similar furnaces in this country, and working on very much the same mixtures, were barely drawing more than two charges, or, at the outside, three charges, in twenty-four hours. He also agreed with the remarks that fell from Mr. Paul. He thought that they should adopt the plan which had been adopted for some time in the States, of one man being responsible for the quality and the working of three or four furnaces. There was no reason whatever why a skilled man should throw away his time simply handling pig iron and charging furnaces.

On the motion of the PRESIDENT, a vote of thanks was accorded to the author, and the following paper was read :—

NOTES ON

THE PRACTICE OF THE COMBINED OPEN-HEARTH  
PROCESS OF MESSRS. BERTRAND AND THIEL.

BY E. BERTRAND, KLADNO, BOHEMIA.

BEFORE proceeding, I beg leave to make a short statement regarding the essence and origin of the process, which is practically based upon the principle of dividing the work heretofore done in one furnace alone between two, or eventually three furnaces, and of perfectly separating the resulting phosphoric and siliceous slags from the metal as it passes from one furnace to the other.

The steelworks at Kladno have, besides their basic Bessemer plant, a limited basic open-hearth plant, consisting of one furnace of 12 tons and one of 22 to 24 tons capacity, for the purpose of working up the scrap and crop-ends resulting in the works. The former of these furnaces was erected upon the same level as the gas-furnaces for melting or heating the pig iron for the basic Bessemer process, since it was intended to use it as occasion demanded also for this latter purpose. It is therefore situated upon a level of about 15 feet higher than the larger open-hearth furnace.

Experience showed that, when working with a more siliceous and phosphoric pig iron, the heats absorbed considerably more time towards the finishing of the heat, owing to the necessity of adding much more lime for the neutralisation of the resulting more phosphoric and siliceous slags, as it took more time to free the metal effectually from the phosphorus.

The position of the two furnaces upon different levels naturally led to the idea of dividing the work between these two in such a way that the upper furnace should eliminate the main bulk of the silicon and phosphorus, while the lower one should perform the finer work of finishing the metal, which may be done far more effectually and with greater accuracy when the highly siliceous and phosphoric slags resulting in the upper furnace are perfectly separated from the metal on its way to the lower furnace.

Since a perfect elimination of the phosphorus is not intended in the upper primary furnace, less lime may be added than would be otherwise necessary, and the quantity of slag to be melted therefore materially diminished.

The slag covering the metal in a thinner sheet also permits the flame to act with greater intensity upon the metal.

The plan of working that was subsequently adopted in this combined way with two furnaces consisted in charging nearly all the siliceous and phosphoric pig iron into the primary furnace, and nearly all the scrap into the finishing furnace, adding in each such quantities of ore, lime, &c., as the circumstances and experience demanded.

The advantages gained thereby in comparison to the former method of working separately in each furnace resulted in an increase of output and a material reduction in the consumption of lime and of basic materials for lining the furnace hearths, since the diminished quantities of slag and their more perfect neutralisation naturally reduced the corrosive action of the slags in the furnace. A saving of fuel must also have taken place in proportion to the increased output, but this could not be proved, because all the gas-furnaces of the whole plant are fed from the same group of producers.

A further material advantage consisted in the possibility of being able to work either with a much higher proportion of pig iron, or even with pig iron alone, or to use as addition to the scrap, pig iron very high in phosphorus, no matter if grey or white, i.e., high or low in silicon, without altering the final result, as long as the pig iron was free from sulphur. Working with more pig iron and ore, a reduction of the loss resulted owing to the reducing action of the carbon, silicon, and phosphorus in the pig iron. I refrain from giving figures regarding the above statements, as they have been previously published in the paper of Mr. Joseph Hartshorne of Philadelphia, read before the American Institute of Mining Engineers in September 1896 at Colorado. This was the state of affairs in the autumn of 1896 when Mr. Percy C. Gilchrist and Mr. W. Panton of Middlesborough, and a few days later Messrs. Alfred Darby and Peter Williams of Brymbo, visited Kladno.

On this occasion two questions were proposed to us, viz. :—

1. By Mr. Gilchrist—May the process be worked to advantage with 100 or nearly 100 per cent. of siliceous and phosphoric pig iron? and if so, with what results regarding the loss respectively, with what gain of metallic iron from the ore?

2. By Messrs. Darby and Williams—What proportion of highly phosphoric (basic) pig iron may be worked with good results?

Based upon these questions a number of heats were made, the actual results of which I may consider generally known through the tables contained in the paper read by Mr. Gilchrist before the Cleveland Institution of Engineers in December 1896. I must, however, remark here, that these heats were all more or less of an experimental nature, owing to the fact that neither furnaces nor men were at that moment prepared for work of this kind.

As already indicated, the open-hearth furnaces at Kladno are regularly worked with pig iron and the scrap naturally resulting in the steelworks and rolling-mills. When working with a larger proportion of scrap, the furnace hearths need not be kept so deep, *i.e.*, they may have less cubic capacity for a given weight of the heat than when working with pig iron alone, where a far greater quantity of additions of lime and ore are necessary for the elimination of the silicon and phosphorus, and the neutralisation of the resulting slags.

The excessively lively boiling of such heats also necessitates a much greater depth of the hearths. The furnace hearths were therefore at that moment not of sufficient depth, *i.e.*, not in proper shape for charging the furnaces to their full capacity when making heats with a high percentage of phosphoric and siliceous pig iron.

This, together with the circumstance that the men at the furnaces were not perfectly drilled for work of this kind, naturally gave this series of heats an experimental character.

I must call special attention to these facts, since I understand that the work then done has met with unfavourable criticism, especially regarding the output and the weight of the heats made.

There can be no doubt that with furnaces properly arranged for the purpose, and with men already drilled for the work, much better results might have been obtained.

Following the question of working alone with the phosphoric and siliceous pig iron, especially with the intention of utilising the reductive power of the carbon, phosphorus, and silicon contained in the pig iron for an increase of the yield of metal from the iron contained in the ore, a series of experimental heats were subsequently made by charging grey forge pig containing about 3·8 per cent. of carbon, 1·0 per cent. of manganese, 1·6 per cent. of phosphorus, and 1·0 per cent. of silicon into the primary furnace, adding, besides the lime, larger quantities of magnetic Gellivara ore, with about 65 per cent. of iron.

The finishing furnace was here actually used only for finishing the heat. It was practically left empty, and only charged with a small quantity of scrap merely in order to have something in the furnace when heating it up to receive the heat from the primary furnace, then adding at the proper moment the necessary additions of lime, ore, and finally ferro-manganese for finishing the metal.

The general results of these heats may be gathered from the accompanying Tables I. and II., pp. 10, 11.

As the tables show, 12 tons of forge pig iron were charged into the primary furnace. Since the heats boiled up excessively, repeatedly causing large quantities of slag to flow out of the furnace doors, a small quantity of pig iron was replaced by scrap in the subsequent heats, which helped to quiet down the metal. The sample ingot from the primary furnace was taken when the metal was tapped and flowed down into the finishing furnace.

The work done by the primary furnace may be illustrated by comparing the average chemical composition of the pig iron with that of the sample ingots from the primary furnace, as follows :—

	C.	P.	Si.	Mn.	
Pig iron . . . . .	3·8	1·6	1·0	1·0	Together, 7·4 per cent.
Ingot from primary furnace .	2·2	0·4	0·05	0·5	...

Hence it follows that the silicon and manganese are practically fully eliminated in the primary furnace, while nearly two-thirds of the carbon and only one-fourth of the phosphorus are left in the metal for finishing in the lower furnace—a fact directly

opposed to the results of basic Bessemer practice, where the carbon is oxidised long before the phosphorus. This oxidation of the phosphorus in the primary furnace before the carbon, is highly important, since it greatly facilitates the work in the finishing furnace, inasmuch as only so much lime need be added in the finishing furnace as is necessary to perfectly neutralise the phosphoric anhydride resulting from the rest of the phosphorus, and it is therefore very easy to make the finishing slag highly basic, and thus insure a low percentage of phosphorus in the finished metal. In fact, the whole work in the primary furnace may be regulated by the amount of phosphorus to be left in the metal when tapping it into the finishing furnace.

At Kladno the finishing furnace is unfortunately situated too far from the primary one, so that the runner leading from one furnace to the other is long and of insufficient incline. It is therefore not feasible to run the carbon and phosphorus in the metal down still lower in the primary furnace, because such a metal, if not excessively hot, will not flow down a long runner of insufficient pitch. As regards the temperature of the heat, this to a great extent depends upon the silicon in the pig iron, whose oxidation helps to give the heat the proper temperature. A certain percentage of silicon is therefore favourable for the process, since its oxidation helps to heat the bath to the necessary temperature, and its further acting as a reducing agent upon the ore added, helps to increase the yield of metallic iron.

Regarding the yield, it cannot be overlooked that it is in this series of heats excessively variable—heat No. 87,102 resulting in an actual loss of 0·3 tons = 2·36 per cent., while heat No. 87,072 shows an actual gain of 0·75 tons = 6·23 per cent. It must, however, be taken into consideration that the pig iron used contains together 7·4 per cent. of carbon, phosphorus, silicon, and manganese, that are consumed by oxidation, so that even a loss of 2·3 per cent. represents a gain of 5·1 per cent. of metallic iron from the ore charged; while, on the other hand, a gain of over 6 per cent. of steel really means over 13 per cent., or 1½ tons of metal gained from the ore.

The great variation in the yield must further be accounted for by the circumstance that in order to make these experimental heats it was necessary to leave the finishing furnace empty for

more than half the time, and then to heat it up when wanted to the proper temperature. This must naturally cause irregularities that may influence the yield more or less favourably, as the case may be. These irregularities would of course be obviated by a perfect plan of two primary furnaces working alternately into one finishing furnace, so that the latter would be perfectly occupied and kept in regular, uninterrupted operation.

The shortcomings of the plant must therefore be taken into consideration when judging the results, and we must so far be contented with the proof that a yield of more than a 100 of steel from a 100 of pig iron charged may be reached when working with siliceous and phosphoric pig alone, a finished product of excellent quality being produced from it.

Regarding the time needed for the heats, the table shows that at the commencement a heat lasted about five hours in the primary furnace, which was decreased to  $4\frac{1}{2}$  hours to  $4\frac{3}{4}$  hours as the men got accustomed to the work; in the same way the time in the finishing furnace was gradually decreased to about two hours to  $2\frac{1}{2}$  hours. These figures show that one finishing furnace will certainly serve for two primary furnaces, the more so as it is entirely in the power of the operator to regulate his work and to determine the proper point of oxidation, and the lowest limit to which he wants to reduce the phosphorus in the primary furnace before tapping, *i.e.*, to fix the most favourable way of dividing the work between the primary and the finishing furnaces. The time of the primary furnace will therefore determine the number of heats that may be made in twenty-four hours by a plant consisting of two primary furnaces and one finishing furnace.

Accepting the time of  $4\frac{1}{2}$  hours for a 12-ton heat in the primary furnace, and taking the time for charging and fettling into account, it is seen that two primaries will make at least nine heats in twenty-four hours. There is, however, reason to believe that with a properly arranged plant, with men once drilled for the work, nine heats of 15 tons may be made in twenty-four hours. These figures of course refer only to the working of siliceous and phosphoric pig iron as given in the above description. How much the output may be increased when liquid pig iron coming directly from the blast-furnace is charged into the primary furnace still remains to be determined by actual experiment.

There can, however, be no doubt that a very material increase of output must result in that case, together with a saving of labour for charging.

The analysis of the finished steel, as also the mechanical tests, prove a fair quality.

Silicon was not determined in the finished steel, since in the presence of so highly basic slags a more than nominal percentage of silicon was quite out of the question.

Sulphur was only determined in the finished steel to prove that no sulphur had been absorbed by the metal in the course of the process, which might be the case when sulphurous ores are used. The sulphur in the pig iron was no higher than 0·05 per cent.

The slags from the primary furnace show a high percentage of silica, thereby also proving that practically all the silicon is oxidised in the primary furnace. When working with pig iron still higher in phosphorus, a slag high in phosphoric anhydride similar to basic converter slag must result from the primary furnace, that may be used for fertilising purposes. The great bulk of the slag naturally results from the primary furnace.

The slags from the finishing furnace are naturally lower in silica and phosphoric anhydride and higher in lime, so as to insure perfect dephosphorisation of the metal.

The comparatively low percentage of iron contained in the slags also proves that a large proportion of the iron contained in the ore has been utilised and reduced to metallic iron.

TABLE I.—Materials Charged and Yield.

Charge No.	Primary Furnace.						Finishing Furnace.						Metal Produced.			Actual			Time in		
	Scrap Tons.	Grey Forge Pg. Tons.	Total Ore Tons.	Lime, Tons.	Scrap, Tons.	Ferro, Tons.	Ore, Tons.	Lime, Tons.	Ingot, Tons.	Scrap and Skull, Tons.	Total Yield, Tons.	In Per Cent.	Loss		Gain		Pr. Finis- hing Furnace, H. M.	Pr. Finis- hing Furnace, H. M.			
													Total Metal Charged, Tons.	In Tons.	In Tons.	In Tons.					
87,033	12.0	12.0	1.700	0.800	2.0	0.120	1.300	0.450	14.120	14.077	0.310	14.384	...	...	0.264	1.87	4.16	2.35			
87,044	...	12.0	12.0	1.900	0.800	2.0	0.120	0.900	0.400	14.320	13.856	0.495	14.351	...	...	0.061	0.36	5.15	2.45		
87,052	...	12.0	12.0	1.800	0.750	2.0	0.120	1.150	0.480	14.120	13.782	0.345	14.127	...	...	0.007	0.05	5.15	3.00		
87,072	...	12.0	12.0	1.800	0.800	...	0.110	1.100	0.450	12.110	12.370	0.495	12.865	...	...	0.755	6.23	4.50	1.50		
87,102	...	12.0	12.0	1.700	0.800	1.0	0.060	0.900	0.450	13.060	12.366	0.385	12.751	0.309	2.36	...	...	5.00	2.15		
87,110	...	12.0	12.0	1.700	0.800	...	0.050	0.900	0.550	12.050	11.121	0.680	11.901	0.249	2.06	...	...	4.35	1.55		
87,125	1.0	11.0	12.0	1.700	0.600	1.0	0.050	0.850	0.550	13.060	12.479	0.695	13.174	...	...	0.114	0.87	4.50	2.15		
87,137	0.5	11.0	11.5	1.700	0.750	0.5	0.050	0.800	0.480	12.050	11.101	0.730	11.831	0.219	1.81	...	...	4.50	2.10		
87,144	1.0	11.0	12.0	1.700	0.700	1.0	0.050	0.900	0.450	13.080	13.123	0.180	13.303	...	...	0.223	1.70	4.45	2.55		
87,149	1.0	11.0	12.0	1.700	0.770	0.5	0.100	1.200	0.500	12.600	12.561	0.600	13.061	...	...	0.461	3.66	4.45	2.30		
87,154	1.0	10.5	11.5	1.700	0.800	0.5	0.050	0.950	0.400	12.050	11.828	0.300	12.128	...	...	0.078	0.65	4.50	1.50		
87,179	...	10.5	10.5	1.900	0.800	...	0.060	0.850	0.300	10.560	9.797	0.775	10.572	...	...	0.012	0.11	4.30	2.05		

TABLE II.—*Chemical and Mechanical Tests.*

Charge No.	Sample.	Analyses of Metals.						Analyses of Slags.				Mechanical Tests.				Remarks.
		C.	P.	S.	Mn.	Si.	From	SiO <sub>2</sub>	P <sub>2</sub> O <sub>5</sub> .	Fe.	CaO.	MgO.	Al <sub>2</sub> O <sub>3</sub> .	SiO <sub>2</sub> per cent.	Fe per cent.	
87,083*	Ingot from primary furn.	2.35	0.300	...	0.053	0.107	Primary furn.	25.36	13.37	7.96	29.70	...	...	...	...	* Sample taken 15 minutes after the addition of the contents of the primary furnace.
	" Finishing "	1.25	0.039	...	0.047	...	Finishing "	14.00	9.60	17.32	36.00	...	...	...	...	
	2nd " Finished material "	0.840	0.008	...	0.082	...	...	...	...	...	...	33.5	...	...	22.7	
87,044	Ingot from primary furn.	1.85	0.252	...	0.029	0.032	Primary furn.	24.41	13.82	6.93	...	...	...	29.0	...	
	Finished material "	0.036	0.045	0.037	0.239	...	...	...	...	...	...	...	...	...	22.7	
87,052	Ingot from primary furn.	2.35	0.432	0.002	0.163	...	Primary furn.	26.60	14.98	11.91	...	...	...	26.0	24.3	
	Finished material "	0.038	0.075	0.043	0.231	...	...	...	...	...	...	...	...	...	...	
87,072	Ingot from primary furn.	1.54	0.434	...	0.061	0.046	Primary furn.	25.70	12.03	6.99	...	...	...	...	...	
	Finished material "	0.061	0.086	0.063	0.255	...	Finishing "	16.80	13.05	11.62	...	...	...	30.0	23.6	
87,102	Ingot from primary furn.	2.22	0.264	...	0.048	0.032	Primary furn.	26.24	13.06	6.99	...	...	...	...	...	
	Finished material "	0.169	0.051	0.026	0.241	...	Finishing "	10.76	9.85	11.83	...	...	...	27.0	28.3	
87,110*	Ingot from primary furn.	2.07	0.400	...	0.036	0.028	Primary furn.	26.92	12.13	6.98	31.20	...	...	...	...	
	" Finishing "	0.782	0.022	0.086	0.032	0.357	Finishing "	10.54	12.80	9.30	48.90	...	...	7.5	54.2	
87,125	Ingot from primary furn.	1.80	0.487	...	0.076	0.149	Primary furn.	29.00	10.88	9.96	...	...	...	...	...	
	Finished material "	0.106	0.086	0.037	0.344	...	Finishing "	9.54	15.10	5.70	...	...	...	26.5	28.6	
87,137	Ingot from primary furn.	2.44	0.237	0.043	0.060	...	Primary furn.	25.20	13.18	8.24	30.30	...	...	12.0	50.8	Hard steel.
	Finished material "	0.624	0.035	0.028	0.195	...	...	...	...	...	...	...	...	...	...	
87,144	Ingot from primary furn.	2.41	0.567	0.063	0.149	...	...	...	...	...	...	...	...	...	28.6	24.6
	Finished material "	0.061	0.170	0.085	0.277	...	...	...	...	...	...	...	...	...	...	
87,149	Ingot from primary furn.	2.12	0.589	0.052	0.102	...	Primary furn.	30.96	8.32	5.62	...	...	...	30.0	28.2	
	Finished material "	0.082	0.098	0.085	0.384	...	...	...	...	...	...	...	...	...	...	
87,154	Ingot from primary furn.	1.76	0.410	0.080	0.163	...	Primary furn.	25.02	11.26	5.62	...	...	...	28.0	27.5	
	Finished material "	0.161	0.052	0.041	0.192	...	...	...	...	...	...	...	...	...	...	
87,179	Ingot from primary furn.	2.12	0.204	...	0.056	0.032	Primary furn.	24.93	12.41	7.68	...	...	...	...	...	
	Finished material "	0.109	0.039	0.059	0.282	...	Finishing "	17.74	10.24	10.78	...	...	...	26.0	24.9	

Regarding the working of highly phosphoric (basic) pig, I have lately made two experimental heats by charging into the primary furnace eight tons of basic pig with 2·5 per cent. of phosphorus, 1·0 per cent. silica, 0·60 manganese, and about 3·8 per cent. carbon. To this were added two tons of Gellivare ore and one ton of lime. Fearing that the metal might, if decarbonised too far, not run down the long runner into the finishing furnace, it was run directly into a ladle and cast. Since one heat was cold, while in the other some metal was lost with the slag, nothing reliable can be said regarding the yield of metal. The analysis of the metal and slag is, however, interesting.

	C.	P.	Si.	Mn.	Slag.			
Pig charged . . .	3·80	2·50	1·00	0·60	SiO <sub>3</sub>	P <sub>2</sub> O <sub>5</sub>	Fe.	CaO.
Metal from the furnace	1·20	0·55	0·03	0·05	19·60	21·88	6·34	35·40

From this it follows that the metal resulting from the primary furnace is also in this case quite of the same composition as the metal from the former heats. It may consequently be finished in the same way and with the same effect. Should experience show that a higher percentage of carbon is desirable, the metal may readily be carbonised as it flows down into the finishing furnace. The gain in carbon would then further result in an additional gain of metallic iron from the ore by means of the reducing action of the carbon in the finishing furnace.

The analysis of the slag proves that it is a phosphate of the character of basic Bessemer slags, and may therefore be utilised in the same way as a fertiliser, thus adding to the profits of the process.

*DISCUSSION.*

Mr. G. J. Snelus, Vice-President, said that the paper just read was a very important and a very interesting one. He took a great deal of interest in it for a very particular reason. Mr. Gilchrist had brought before them conclusively the fact that all the elements found in pig iron—the carbon, the silicon, even the phosphorus and the sulphur—had the power of reducing oxide of iron, and therefore of increasing the yield. It would be remembered that in 1872 he read a paper on the Danks process, in which it was shown that the yield of puddled bar was considerably in excess of the charge of pig iron which was used for producing the puddled bar. It was suggested to the Commission that went to America to examine that process that they had been hoodwinked, and that there had been more iron added when they were not there, and that that accounted for the yield. He knew that could not be the case, because the members of the Commission took day and night turns, and were never absent from the furnace. Therefore they were perfectly assured that, whatever the results, they had been honestly obtained, and that there must be some other explanation of them than an attempt to defraud. He came to the conclusion that all the elements which entered into the composition of the pig iron—the silicon, the carbon, the sulphur, and the phosphorus—had the power of reducing oxide of iron, and that it was in that way that the extra yield of metal had come about.

When he returned, their worthy Past-President and friend, Sir Lowthian Bell, came down to Dowlais to interview him about the results. There were also present their lamented Past-Presidents, Mr. Edward Williams and Mr. Menelaus, and they had a long discussion on the question. He remembered well Sir Lowthian Bell's remarks. Sir Lowthian said, "Well, Mr. Snelus, I am quite prepared to admit that carbon will reduce the oxide of iron, and I think it barely possible that silicon will, but I am not quite prepared to admit that the phosphorus and the sulphur will reduce the oxide of iron."

In order to test the correctness of his deductions, he went

to the expense, as he had previously mentioned, of purchasing a quantity of the rather costly pure silicon, which he mixed with Bilbao iron ore, and placed in a lime crucible, which was put in an outer wrought iron crucible, the lime crucible being thoroughly surrounded by finely-powdered lime. That was placed in a Siemens furnace, and on taking it out after a prolonged action, he found that even solid silicon had the power of reducing oxide of iron—that the Bilbao ore had been reduced to metallic iron, and that the silicon had been oxidised. There could, therefore, be no doubt that silicon had the power of reducing oxide of iron at that high temperature, and he therefore came to the conclusion that he was perfectly correct in deducing the fact that the extra yield of puddled bar was due to this action of the different elements which the metallic iron contained having the power to reduce oxide of iron. These chemical facts were now thoroughly accepted, but he thought the present was the first occasion on which the actual results of such a process had been placed fully before them.

He had long pondered over this question, and several years ago he devised what he called a "reaction process" for getting a large yield of iron by treating pig iron containing a large quantity of carbon and a large quantity of silicon directly with oxide of iron. He devised a rotating furnace, in which he proposed to bring together the molten pig iron containing, as he said, a large quantity of carbon and silicon especially, and also phosphorus if convenient, and bringing that into contact with molten oxide of iron directly, thus producing a reaction process. He had no doubt that that reaction would be a very violent one, and the results observed by Mr. Gilchrist showed that it was so. He did not, unfortunately, get that into practical work; but, on making some inquiries, he found that their American friends had again been to the front. He did not remember at the moment which firms had made those experiments, but he was told that some firms in America had tried a modified form of the process, and that they had got a large extra yield of metal—that the process was a very violent and a very sudden one, but that theoretically all the conditions were exactly as he had presumed they would be.

He was rather surprised that it had not been carried out here.

Unfortunately he had not been in a position which enabled him to make experiments or to attempt to bring it into practical success, but he believed that there was a field for it, and that a reaction process, where the pig iron and the molten ore were brought into contact under high temperature, would in the future lead to very important results. Further than that, the temperature required need not be produced altogether externally. If they calculated the thermal units produced by the oxidation of carbon and silicon, and the thermal units used up by the reduction of iron oxide, it would be found, as he had already calculated out, that there was no great loss of temperature in the process, and that, in fact, the reaction produced the temperature necessary for the process, provided they began with both the pig iron and the oxide of iron at a sufficiently high temperature.

There was no doubt that, in order to carry on the process, they must use a basic lining. He considered that it was the first furnace which was used with the basic lining which, to a large extent, produced the results that he suggested could be produced in a rotating furnace, but without the extraneous heat supplied. He should be very glad if, in the future, this idea bore some fruit. It was quite evident that there was the beginning of the thing here. He thought the results which had been appended to the paper showing the reduction of the carbon in the first furnace down to 1·2, the phosphorus down to 0·55, the sulphur down to 0·3, and the manganese to 0·5 showed that very nearly the whole process had been produced in that furnace. They had practically almost got to the proper steel condition in the first furnace; they had taken out a large part of the phosphorus; the sulphur was low; they had taken out the manganese, and the carbon, he had not the least doubt, could be reduced down to, say, the carbon required for steel rails with very little modification of the arrangements. He had ventured to put these points before the meeting, because he thought they were intimately connected with the subject in hand, and he had great pleasure in bearing testimony to the good results obtained by the originators of the plan, and to the ability which Mr. Gilchrist had shown in bringing the matter publicly before them.

Sir LOWTHIAN BELL, Bart., Past-President, had not intended

to take part in the discussion, until he heard the few words which fell from his friend, Mr. Snelus, with regard to a conversation they had on a cognate subject a good many years ago. He did not recollect the interview, but he had no doubt that Mr. Snelus had correctly quoted what he said on the occasion. At that time he had already made several experiments, and had come to the same conclusion which Mr. Snelus had just described, namely, that the oxidation of the phosphorus was necessary in order to get the necessary heat for the process. It was a very difficult thing to say exactly what took place in the converter. It was quite clear that the whole of the iron had not been reduced in the way they would like to see it, because, if the whole had been reduced, they ought to have had none of it in the slag, whereas there was a considerable quantity. Whether the phosphorus performed its part of the operation by acting as a reducing agent to its full extent or not, it would be extremely difficult to say ; it might be so, and the iron that was found there might be iron oxidised during the process itself—that was quite possible. They certainly did know that carbon of itself was capable of almost completely reducing oxide of iron. In fact, carbon was formerly, in the assay of iron ores, the agent employed by Dr. Percy, by Mushet, and many others. Still it was quite possible that they might succeed by taking oxide of iron and introducing phosphorus into it ; but he thought there would be a difficulty in reducing the oxide of iron completely with phosphorus, and the same with silicon, although silicon would be more easily employed, and be more manageable than phosphorus would be, because there would be a considerable volatilisation of the phosphorus. He agreed entirely with what Mr. Snelus said, that the question was one deserving of very ample consideration. He had seen the two processes on the Continent, and he thought it quite possible that, with further experience, much valuable information, and probably economy of production, might be achieved.

Mr. G. A. WILSON said that he had read Mr. Gilchrist's paper on the Bertrand and Thiel process some time ago. Feeling some difficulty in accepting some of the arguments in it, he came to the conclusion that he would like to see the process

at work before he could believe what was said about it. The consequence was that he went to Kladno last week, and watched them while they wrought five charges. He went there to look at the process purely from a steelmelter's point of view. He wanted to see how they handled the metal in the finishing furnaces, as he could not come to the conclusion that the metal would be in a fit state in so short a time to handle in the ladle as they claimed for it. As he had said, he saw five charges wrought. All the metal and the scrap were charged in the primary furnace, the finishing furnace being left entirely empty, except for the lime and the ore which were thought to be required. The first charge had 20 per cent. of scrap; the second charge had also 20 per cent. of scrap; the third had no scrap; the fourth charge had 10 per cent. of scrap, and so also had the fifth charge. The carbon was 3·6, the phosphorus 1·5, the manganese 0·6, and the silicon 1 per cent.; that was the composition of what was charged.

In the first charge the time in the primary furnace was 4 hours 40 minutes; then they ran it down into the finishing furnace, which took about 2 minutes; and the charge was tapped in 1 hour 50 minutes. In the second charge they took 5 hours 10 minutes in the first furnace, and 1 hour 20 minutes in the finishing furnace. In the third charge they took 4 hours 5 minutes in the first furnace, and 3 hours 45 minutes in the finishing furnace—that was the one with all pig iron. In the fourth charge they took 5 hours 10 minutes in the first furnace, and 2 hours 5 minutes in the finishing furnace. From what he saw, he had come fairly to the conclusion that the process was one which, by very little practice, could be wrought successfully by capable melters in the making of basic steel. Fifth charge, 5 hours 20 minutes first furnace, 1 hour in finishing furnace.

*Analyses of Finished Steel.*

		Per Cent. C.	Per Cent. P.	Per Cent. Mn.
1st Charge.	No. 685	0·11	0·02	0·34
2nd ..	.. 693	0·10	0·009	0·37
3rd ..	.. 715	0·09	0·01	0·32
4th ..	.. 722	0·20	0·01	0·51
5th ..	.. 790	...	0·04	...

1897.—i.

I

Mr. JAMES RILEY, Vice-President, said the process described in the paper was essentially the ore process, which used to be named by Ritter von Tunner "the Landore Process;" only Dr. Siemens had not at that time available the basic lining, the basic hearth, on which to work; but Dr Siemens always asserted that there should be from the furnace a gain of yield due to the use of the ore, and worked it out—as they all knew, and had read many times in his speeches—by the reactions named by Mr. Snelus that morning. One could see the great desirability of the process in certain ways with such slag as that referred to in Mr. Bertrand's additional note; the yield of iron was undoubtedly accounted for there. But what he was somewhat at a loss to understand was where the advantage of the two furnaces came in. He thought Mr. Snelus was going to finish his remarks, when he had referred to the reactions which had taken place, by saying, "Having carried the operation to such an extent, why then transfer the metal at that stage into another furnace?"

In 1881, he thought it was, Mr. Gilchrist was at Newton for many weeks, and made various experiments in an open-hearth furnace which he (Mr. Riley) provided for him. In that furnace there were arrangements made for tapping off the slag at a certain stage, and then after the slag, as they thought, had taken away the phosphorus from the metal, finishing in the ordinary way. A great many difficulties arose which were now ancient history; but what he was at a loss to understand was—Why tap the metal from the first furnace into another furnace, rather than tap off the slag which you were wanting to get rid of and finish in the first furnace? Why have the two furnaces and the duplicate operations? He should really like to have some explanation of that if it were possible to give it. They knew the contingencies that arose. Reading between the lines of the communication they had received that morning and what one had heard, it was evident that there were difficulties now and again. They knew there must be. Most of them had had experience of the transferring of metal—pasty semi-steel, if they liked to call it so—down runners in the various operations met with in practice. There must now and again be considerable waste of metal, even if there was no additional expense—no *per contra* to the economies which were

gained by the various operations. Why undergo all this if the thing could be done just as well in the one furnace by taking away the obnoxious slag?

Many years ago—he thought it was in 1885, at the Glasgow Meeting, when some such point as this was under discussion—on the authority, he thought, of Mr. Gilchrist, and from his own experience with the furnace referred to, he made the statement that the phosphorus went off early in the operation. Many of those who heard that statement considered it was utterly incredible. It could not be done. That was one of the points that he made then in favour of the open-hearth method of working the basic process in contradistinction to the Bessemer method. All the authorities disbelieved that point, which was now confirmed very clearly, and which was one of the great advantages of the open-hearth over the Bessemer basic process.

Mr. BERNARD DAWSON said the paper was out of the usual course, because it mentioned a paper on the same subject that was read in Middlesbrough, and also a paper by Mr. Hartshorne, read before the American Institute of Mining Engineers; but there were now facts and conditions to be considered that were not previously before them. Before they went back from this meeting intent on pulling down their works and making room in confined spaces for two furnaces, or (as Mr. Gilchrist told them at Middlesbrough) six furnaces, to do the work that the best practice was now doing in this country with one, they should look at the matter from an engineering point of view. It was a very highly painted picture; it was a very nice picture, and it was a very appetising subject from a chemist's point of view; but he should not think, however interesting it was, and however much one might be tempted to enter into the chemical points of view from the position of an amateur, that with people like Mr. Stead and Sir Lowthian Bell present, any one would presume to occupy the time of the meeting upon that aspect of the question; but as nobody had criticised Mr. Hartshorne's paper, nor the paper which was read at Middlesbrough, from an engineering point of view, he should like to impress upon them the importance of looking at it from that standpoint.

The President had a knowledge second to none of the existing

open-hearth steelworks in this country, and he asked him—he asked any member present at the meeting—whether he could point to any place in this country where they could get a series of furnaces one behind the other at different levels. Apart from the difficulty of getting the steel down these runners for these immense distances—and they were told at Middlesbrough that it would be 300 feet from one furnace to another—there was a difficulty in dealing with the raw material and the finished product at the different levels. The question of levels they could easily get over, because instead of running the steel—subject to cooling, subject to oxidation, and subject to waste—in open runners along the ground (which would be in practice very objectionable), they could arrange to transfer it by cranes from one furnace to another. And surely they could get over another difficulty which had been experienced in connection with the furnace-hearth by emptying a ladle filled with molten iron or molten steel from one furnace to the other. They had got two or three or four, or some other unknown number of furnaces; they had got an increased quantity of chimneys, gas-producers, flues, and charging apparatus, and also increased roofing and additional land, which in many places, such as Sheffield and some of the larger towns, was a very important consideration. What had they to put against all these? If, as appeared from an engineering point of view, the tonnage which could be got out by this process was to be confined or regulated by what could be got out of the secondary furnace, then would all this extra expenditure be repaid by the increased output in tonnage per week?

On the question of desiliconising the metal, that should be left to the chemists; but when the English steelmakers insisted upon having their pig iron delivered with a little less sand upon it, and the pig iron was cast in chills or in ashes instead of being covered with sand, one of the difficulties of excessive silicon would be got rid of, and then they would have to do what seemed to be a very extraordinary thing. They were told in the paper to put silicon in the pig iron on purpose to make it hot enough to run down these long runners from one furnace to the other!! Then there was the question of men. If they could get men in this country to tap the first furnace, throw their tools down, run

along following the steel in the runners, and handle it at the other furnaces, there might be something to be said for it; but he did not think they would find any men who would do that. And besides this, if the charges were to be got out in as short a time and as quickly in succession as appeared to be possible, it would not be a question of getting the men to run from No. 1 furnace to No. 2, and from No. 2 to No. 3, but the whole of their time would be occupied, and very fully occupied, in fettling up the first furnace, and charging it and getting it ready again; that was, they would have to engage three sets or four sets of men to do the work which one set did now.

Of course, against that they would have to set any increased output which could be derived from the secondary or finishing furnace. There was a good deal to be said about extra capital and depreciation, and there were a great many engineering details which it would be very interesting to endeavour to elicit a satisfactory reply upon, if the time was not already getting late, and if there were not so many people in London who had been to Kladno and had seen the process, and were very much better able to speak upon it than those who had only seen diagrams and had heard Mr. Gilchrist's paper read at Middlesbrough—a paper which practically exhaustively treated the subject, with the exception of the purely mechanical details. The labour and trouble involved in preparing that paper he did not think any one would imagine except those who had done it. M. Bertrand's paper appeared to be more or less of an apologetic character, making out that the people who had been to Kladno did not see it at its best. The author had endeavoured now to put the best before them, and all he (Mr. Dawson) would say was, that before members went away intent upon building entirely new works, where they could get sufficient land to lay down furnaces in the order and respective positions that this process required, they should endeavour to elicit a few facts about the cost of up-keep and maintenance, of labour, of extra land and extra chimneys, of platforms, and so forth, so that they could set against the chemical advantages and the undoubted increased output the extra cost of such up-keep and maintenance.

Mr. J. E. STEAD, Member of Council, had nothing to add to

what he had stated in a discussion upon a very similar paper read before the Cleveland Institution of Engineers. At that time he pointed out that the practical value, so far as he could see, of the process would be that in Cleveland, and in other districts in all probability, they would be able to desiliconise any ordinary No. 3 or No. 4 iron which was sufficiently low in sulphur in the acid-lined furnace, and then transfer it afterwards to the basic furnace. That being the case, it would not be necessary, then, to make a more expensive character of basic pig iron. Beyond that he could not say that he could see very much in the process of value for their purposes in Cleveland, but there might be for all that.

With reference to the larger yield which had been referred to, and the chemical reactions which took place between the metalloids and the oxides of iron, he had many years ago made experiments to ascertain whether those metalloids really did reduce iron from the oxide of iron in the cinder, and the results, which were given in an appendix to Mr. Gilchrist's original paper on this process, showed clearly that on a small scale, when the action was rapid, the phosphorus and silicon in pig iron did act upon the oxide of iron and reduced it, and there was a very much larger amount of iron precipitated into the steel than was represented by the simple weights of metalloids removed—precisely what Mr. Gilchrist had pointed out—and they ought to have very large yields; but in practice he believed they could not have those theoretically large yields for reasons which were not altogether clear. His own impression was, that the oxides of iron in an open-hearth furnace did not behave in the simple way that they expected them to do, but that the action was complicated. First of all, in all probability, the peroxides of iron in the ore added were partially reduced to magnetic oxide, and even to protoxide, without the iron being precipitated, and the cinder thus partially deoxidised, on passing to the surface, would be converted by the oxygen of the air into magnetic oxide, and this oxide of iron passed down by circulation and communicated its oxygen to the metal without being completely reduced to metallic state; it then would rise to the surface again, and become magnetic oxide. In fact, he believed that a silicate of iron could, and did, act as an oxygen

carrier, and that was the reason why practically much larger yields were not obtained. He knew that if they took a large quantity of haematite ore and mixed it with pig iron, the simple reaction  $2\text{Fe}_2\text{O}_3 + 3\text{Si} = 2\text{Fe}_2 + 3\text{SiO}_2$ , did not take place, but, first of all, the oxygen was taken away from the peroxide, leaving magnetic and protoxide, and they had instead of an increase a loss. If, however, they commenced with a protoxide of iron, then the reduction did take place if the mixture was very intimately and rapidly effected. If they could subdivide the metal, and bring it into contact molecule by molecule with the cinder, they would have an almost instantaneous reaction; they would have steel produced as quickly as when they made tartrate of soda by mixing carbonate of soda and tartaric acid together, provided there was sufficient heat to keep them very fluid. In practice, however, they could not do that. Any process by which they could cause rapid intermixture of the cinder and the metal would shorten the process. His own impression was that transferring very hot steel from one furnace into another furnace where there was a lot of cinder highly heated, would be very similar to the action which took place when one stirred up carbonate of soda and tartaric acid together.

Mr. F. W. HARBORD said that all those who had had anything to do with basic Siemens practice must always feel very much interested in the question of the complete reduction of oxide of iron to metallic iron by the metalloids. It must always be remembered that it was doubtful if, under the special conditions, the metalloids were capable of doing this, as in some cases, at all events, it seemed probable that their reducing action did not extend further than the reduction of a higher oxide of iron to a lower oxide, this lower oxide being again oxidised by the air, as pointed out by Mr. Stead. Again, it was always necessary to have a reasonable excess of oxide of iron in the slag, even to the end of the operation, as otherwise the final oxidation of impurities would not be possible. He remembered one of the earliest experiments he ever saw carried out in the basic Siemens, where they were using a protoxide of iron,  $\text{FeO}$ —in fact, a reheating furnace cinder. They found then that the reactions were much more rapid than with ordinary red haematite, and it seemed probable that in

the lower oxide FeO did act more vigorously. They had, in the end, to give it up, because they found its action was so energetic towards the end of the operation that they got over-oxidised metal, although this was no doubt due to some extent to using too large quantities of the cinder. With reference to using such a large percentage of phosphorus and silicon as Mr. Gilchrist had suggested in his paper, he thought that unless they added carbon, as had been suggested in M. Bertrand's letter, during transference from No. 1 furnace to the finishing furnace, the limit would be found in practice not to exceed much over 2 per cent. of phosphorus. To make the basic process a success, it was necessary to have left in the bath of metal a comparatively large percentage of carbon after the bulk of the phosphorus had passed out. If the carbon was removed with the phosphorus, they would never get a low phosphoric steel.

If, as suggested, they removed 75 per cent. of phosphorus and carbon in the primary furnace, and then rebarurised by Darby's process and finished in another furnace, they might get excellent results, even from very high phosphoric pig. The chief point about the Bertrand and Thiel process, as it seemed to him, was that they got rid of the great bulk of the phosphorus in the first furnace; they removed the phosphoric and silicious slag, and then finally they finished in a furnace with a slag rich in lime and free from phosphorus and silicon. Mr. Riley had pointed out the disadvantages of having two furnaces, and had suggested that it might all be done in one. He should be loth to criticise the remarks from a gentleman of Mr. Riley's very large experience, but it seemed to him that one disadvantage of doing it all in one furnace was that they had then to add a lot of cold material just at the time when they could not afford to cool the bath of metal, viz., towards the end of the heat. If they did it in two furnaces, they would run the molten metal on to a furnace where there were hot materials. Mr. Snelus had referred to some experiments that had been conducted in the States; he thought probably they were the experiments carried on by Mr. Benjamin Talbot with what was known as the washing process, which was suggested, no doubt, by Sir Lowthian Bell's classical experiment years ago in running molten iron through molten oxide. When Mr. Talbot carried out the experiments, he was using a

low phosphoric pig, and this low phosphoric pig produced, of course, a comparatively low phosphoric slag. He took the slag from the furnace, added a little oxide of iron to it, and ran the molten metal for another heat through it; this desiliconised and partially dephosphorised the metal, and it was then transferred to a Siemens furnace to be finished.

If the mechanical details could be worked out by practical engineers, those were the lines they ought to go on. They wanted a large sort of mixer or basic-lined furnace in which they could have a basic slag fairly oxidising—perhaps very oxidising—in a molten state, so that they could run the metal through this slag, and then they ought to be able to practically desiliconise in a few minutes, and to partially decarburise and dephosphorise it. He thought he was right in saying that in Sir Lowthian Bell's experiment Sir Lowthian got rid of 50 per cent. of the phosphorus by running the molten metal through the molten oxide. If that were so, they ought by some such processes to be able to largely dephosphorise and desiliconise in a few minutes, and to transfer the purified metal in the molten state to a Siemens furnace, thus doing away with the necessity for any mechanical chargers and their attendant difficulties.

Mr. EDWARD RILEY said that at the Bilston Works they had tried a process of desiliconising the pig iron in an acid-lined converter first of all. The pig was very siliceous, and they worked for some time desiliconising the pig in an acid converter, and then transferring it into a basic converter. The practical result was that the labour it entailed did not pay, and they very soon gave it up; theoretically it was correct, but practically they found that it did not pay. Their present practice was to add to the charge a certain amount of tap-cinder; the result was that they got a very considerable advantage in the yield and a higher percentage of phosphorus in the slag. When they began the basic process the yields were running up as high as 27 cwts. per ton, but now they were about 23 cwts. per ton, so that they had practically used oxide of iron in a basic converter.

Mr. E. WINDSOR RICHARDS, Past-President, said that Mr. James Riley's pertinent question had induced him to get up and say

a few words. He was very much interested in the paper, and Mr. Gilchrist had kindly circulated an enormous amount of information regarding this process. Mr. Snelus was certainly wrong in saying that one furnace did the work ; the figures showed that there was ten times too much phosphorus in. There must be a furnace which would do the work better than that, he thought, or they would not get engineers to accept basic steel. They found in their early experiments in dephosphorising that the trouble was not getting out the phosphorus to that extent ; the trouble was to get the phosphorus down below that. If they wanted to get phosphorus down from say 0·5 to 0·3, it was a far more difficult thing than getting phosphorus down from 2½ to 0·55. In order to get over that difficulty and save waste of metal, they used to pour off the slag. By analysis they knew exactly that the phosphorus came down to about that in the Bessemer converter. They then poured off the slag and put down fresh lime, and they found that the phosphorus then or at the end of the blow was eliminated much more quickly than if they had added a sufficient quantity of lime in the first instance. That induced him to say that a second furnace to make steel absolutely low in phosphorus was most desirable—at least he fancied that must be the reason why Messrs. Bertrand and Thiel had introduced the second furnace.

There was a very good reason why they should give the greatest possible attention to what was brought before them in the paper—that was that ores for making steel by the ordinary Bessemer and Siemens-Martin processes were getting very scarce, and very poor in quality compared with what they were. It would be very much better for their own country if they could improve the basic process of dephosphorising our own ores. There was an abundance of ores in Cleveland, in Lincolnshire, and in Northamptonshire, and we for one would very much prefer it if they could possibly improve the basic process for a certainty to a very low point, and so obtain the confidence, which he was afraid they had not quite got, of English engineers, as was the case on the Continent. He thought they might better British industry in that way rather than by encouraging the importation of ores from Norway and other distant parts of the world. He did not know how far Mr. Riley's experiments went,

but he suggested to that gentleman for his consideration whether there was not, as he had suggested, a difficulty of eliminating the last traces almost of phosphorus as compared with the elimination of phosphorus when the percentage was high.

Mr. G. J. SNELUS, Vice-President, said that he could see no reason why the phosphorus should not be reduced in the first furnace if they would take care to keep the silicon in the slag lower. It would be noticed that the silicon in the slag was nearly 20 per cent. There was no reason why it should be so high as that. He contended that the phosphorus only went out when the silicon in the slag was low, as only a very basic slag had the power to absorb the phosphoric acid thoroughly.

Mr. J. W. SPENCER asked what was the cost of this process as compared with that of the ordinary method. He thought it was clearly demonstrated from the chemical point of view that good steel could be made by this arrangement, but the paper contained no figures showing the comparative cost, which was the vital point for their consideration.

Professor H. BAUERMAN asked how far the process would be available with ores of an inferior quality. They were told in the paper that if they put fourteen tons of metal into the furnace they got fourteen tons of ingot out; but there was in addition to that as much iron put into the two furnaces—65 per cent. of good ore—as would make two tons extra of pig iron, so that they really were working with sixteen tons of iron in the furnace and fourteen out; and it was easier, so to speak, to flux away that oxide of iron instead of taking it back from the metal that had been previously reduced. But it was exceedingly good ore, and the waste must have been very considerable. Supposing there were 66 per cent. of iron in the ore, the weight of the slag would seem to be about twice the weight of the finished metal, and that would be rather an incumbrance. Supposing they were using an inferior ore containing more silica, they would then probably get a great deal more waste, because they must flux away the silica first with lime or ferrous oxide; and until whatever silica existed there was fluxed with ferrous oxide or lime, or with a

combination of both—and ferrous oxide went easily into combination with silica—they could not get any very good reducing effect from the metal. He took it that the process was only suited for using exceedingly good ore, and there was not very much 65 per cent. iron ore to be got now.

The PRESIDENT said there was no doubt they were all anxious, if possible, to increase the output of the Siemens furnaces. At present the one drawback it had was that it did not give as large an output as the Bessemer converter. If they went back to Mr. Kupelwieser's plan, by which he, first of all, desiliconised in the ordinary converter, and afterwards transferred the metal to a basic or an acid-lined Siemens furnace, he thought there was a prospect of a considerable increase of make. Within the last week or ten days they had been making experiments in that direction at Dowlais, and he thought that, on the whole, they were rather promising. Another matter which might be worth mentioning, was that about thirty years ago, when he visited America, there were great expectations, founded upon a system invented by Ellershausen, in which molten iron and powdered oxide of iron were run together. They tested that at Dowlais, and they had some very peculiar results; but at that time they had not the advantage of a basic Siemens furnace for using it. He thought that if to some extent the Ellershausen system were again adopted, they might both ease the trouble of charging the Siemens furnaces, and at the same time get a very large proportion of the gain from the iron ore referred to in the paper.

Mr. P. C. GILCHRIST, Member of Council, said that his friend Mr. Bertrand had unfortunately lost his voice, and had in consequence been unable to come over and read his paper, and had therefore asked him to take charge of it for him. He did not pretend to be able to answer all the questions that had been put, but he would deal with those that he could, and leave Mr. Bertrand to answer the others, and to correct him where necessary by correspondence in the Journal.

General approval of the system had been expressed by Mr. Snelus, but he said, Why not reduce the phosphorus in the primary furnace still lower? The best results in regard to

reducing the phosphorus in the primary furnace so far had been down to 0·3 and 0·2 per cent.; but he did not himself think that it would be at all advisable to reduce the phosphorus in the primary furnace, or the carbon either, as low as they might in that furnace. He looked upon the primary furnace very much as in the old days they looked upon the refinery working for the finery. In the old days the refinery prepared the pig iron, no matter what its composition was, down to a uniform pitch, and then the finery dealt with that. It would be remembered that in the refinery, if the metal was too solid it was wrong, and if it was too honeycombed it was wrong; there had to be just the right pitch, and they had practically to get something of a uniform quality to treat in the finery. So, again, in Mr. Bertrand's primary furnace, by adding the whole of the ore, as they did at Kladno, with the pig, they could get, as was shown in the paper, the phosphorus down to an average of 0·4, and they could keep the carbon up to 2 per cent. or more, which was an enormous advance upon the basic practice of to-day. It avoided that nasty business of pigging back. Pigging back meant that they were keeping almost wrought iron liquid in the furnace, which was very severe on it. When they ran the metal from the first furnace into the finishing furnace, they had the oxide on the bottom, and they got rid of the 2 per cent. or the 1½ per cent. of carbon and  $\frac{4}{5}$  of phosphorus in a quarter of an hour; and whether they took one hour or two hours to finish that metal depended, he thought, upon the skill of the workmen. In the five charges that Mr. Wilson watched, there were two cases in which they eliminated the remaining metalloids, and finished the metal in an hour and an hour and twenty minutes. In the case of the hour, what work did they do? They reduced the carbon from 1½ per cent. and the phosphorus from 0·3; they got the carbon down to a tenth and the phosphorus to 0·04. When he said a quarter of an hour, he was referring to his own paper as regarded the time for eliminating the remaining metalloids. He did not agree at all with Mr. Snelus in thinking it would be desirable to push the phosphorus or the carbon to the lowest limit that they could do in the primary furnace; they must have a fluid metal to run to the other furnace.

It had been asked by Mr. James Riley, Why have two

furnaces, and why not tap off the slag and do it in one? About that they were all agreed that, if they could take fluid pig iron and shake it up with fluid oxide of iron, that would be perfection, and they would get the elimination of the metalloids instantaneously. But accidentally, he thought, something almost as good as that had been hit upon. If they made the oxide of iron and lime pasty, and then ran molten metal upon it, they got an extraordinarily rapid reaction. As he had said just now, they were able to get  $1\frac{1}{2}$  per cent. or 2 per cent. of carbon and  $\frac{1}{2}$  per cent. of phosphorus out in a quarter of an hour. That was the advantage of the two furnaces, that they were able to get out 65 per cent. of the metalloids in the first furnace; then they gave it a fresh dose, not of cold ore, not of cold oxide of iron, but hot oxide of iron (the reaction would not, of course, take place unless the oxide of iron was hot); that, coupled with the getting rid of the slag, was the advantage of the second furnace—at least he thought so.

It had been asked by Mr. Dawson, Why have a lot of furnaces to do the work of one? and he spoke about six. He thought it only fair to say that Mr. Bertrand was much more modest than he himself was in what he expected the process to do, and therefore he would, as regards speed, only quote from the paper. Mr. Bertrand was the manager of a large works, and he deliberately stated, on page 8 of the paper, that he considered he could get nine charges from three furnaces, which was at the rate per furnace of three charges in twenty-four hours. Now if it could be done at the rate of three charges in twenty-four hours from all pig, that was 50 per cent. quicker than any furnace on the single furnace system had ever yet done; so that all Mr. Dawson's questions about more room, more plant, more capital he did not quite see the necessity of, because if they were going to get 50 per cent. more out of the same number of furnaces, that would mean that they would want less roofs and less furnaces, because it was the rate per furnace which governed those things. Those nine charges, he thought, certainly were not too sanguine an estimate. He made a mistake at Middlesbrough when he said there was a 300-foot runner from the first furnace to the finishing furnace. Mr. Wilson had measured it, and found it to be 37 yards.

Could it be done by ladle? Mr. Bertrand, in the last letter he had from him, seemed to think the runner was the best thing. It was a practical point as to whether they could have the tap-hole large enough to run it into a ladle, and then transfer into another furnace. Certainly if they could do it by a ladle, then all existing plants would come in; if they could not, it meant rebuilding entirely. Mr. Dawson said the paper was apologetic. Of course it was. Mr. Bertrand was in the same position as a good many other gentlemen. He had got his works, and he had to make the best of them, and he was not prepared to put down fresh plant. He had only one primary furnace and one finishing furnace, and certainly the result that ought to be obtained could not be obtained with fewer than two primary furnaces; probably one ought to have three.

He took it that Mr. Stead did not think that the yield which theory expected would be got out. Mr. Bertrand had shown what he had got, and the question must rest with somebody who would have sufficient enterprise to see whether any fresh facts could be got by putting down two or three primary furnaces to work for the one finishing furnace, and then they would see. He did not agree with Mr. Stead on the point about the action not taking place sufficiently quickly. As he had said just now, by making the ore hot before they ran the metal upon it, they got that instantaneous action which they knew was so desirable.

The statement was made by Mr. Harbord that there was a limit of phosphorus because of the carbon. That would have to be settled by people trying, but he did not at all agree with Mr. Harbord. If they had got more phosphorus to deal with, they would have more oxide of iron and lime to make hot before they ran the metal upon it, and therefore he did not believe it would make a ha'porth of difference.

He observed that Mr. Stead agreed that it was more reasonable to heat the lime and oxide of iron to the temperature that was necessary for chemical union to take place before they allowed them to come in contact with the pig iron than it was to throw cold ore into the bath.

Mention had been made by Mr. Edward Riley that desilicising in the Bessemer converter did not pay because of the labour. The whole thing depended upon what output and yield

could be got from the furnace, and, of course, in his case at Bilston, Mr. Riley did not get an increasing yield.

In conclusion, he hoped that the Bertrand process would enable their make of 600,000 tons of basic steel per annum to be increased somewhat towards that 4,300,000 tons which the Germans made last year. Ours was a paltry percentage of our total steel made, whereas theirs was just the other way about. He thought that this combination of furnaces in English hands would be as advantageous to us as the basic process had been to the Germans. We had got the phosphoric pig, and the ore which was required for the job we could import. It seemed to him that by this process the preparation of basic pig would become unnecessary, as by it 100 of ordinary grey phosphoric pig (with under 0·1 per cent. sulphur) would produce 100 of steel, and at the rate of three charges per furnace per twenty-four hours.

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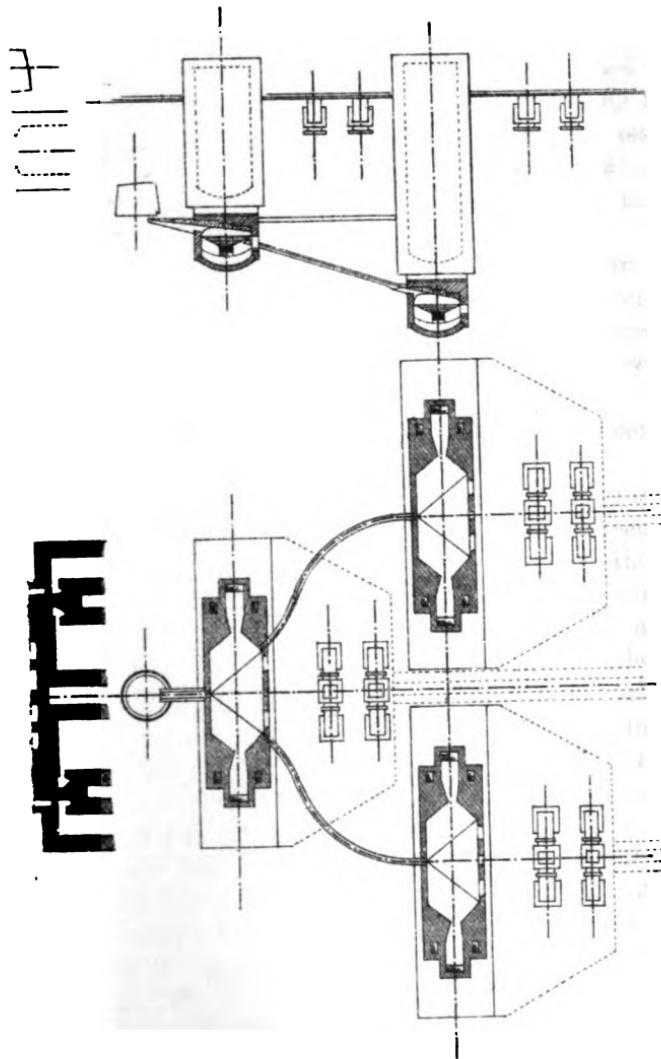
#### CORRESPONDENCE.

Mr. J. W. WAILES much regretted he was unable to be present to hear the author's paper and the discussion upon it. The basic open-hearth process was a question of very rapidly growing importance; besides, he had had a strong personal interest in the matter from the time of its introduction. He was very glad to add a few words, even if they were not of any marked importance.

It should be observed that this Kladno process had been brought under the notice of those interested in the manufacture of steel in a singularly enthusiastic way—enthusiasm which some might consider somewhat out of proportion to the importance, not of the basic open-hearth process, but of this particular point in its development. At the same time, it was manifest that the fullest particulars had been given in the most unreserved manner, and with very distinct sincerity. No doubt there had been a good deal of labouring of the mountain, and sanguine people expected a rat at least, and were inclined to be impatient with what at first sight certainly looked like a mouse. The outcome was undoubtedly disappointingly mild—viz., doing in two

PLATE XIII.

Ballantyne, Hanson & C° Edinburgh & London.





furnaces what was generally done in one. As a matter of course the questions follow:—Why use two furnaces if one will do? Why duplicate your adverse chances, if indeed in the complication you don't square their number? Why not tap the slag and add fresh lime and oxide, and quite simply finish in the same furnace?

Running the half-finished charge down a slow-pitched gutter for 37 yards to another furnace had not a very promising look.

It had been stated very plainly and certainly what reactions ought to take place; that in working under right conditions the yield should be large and reactions rapid. That was the first point to be kept in view.

It must not be forgotten that the difficulty was not in taking up  $2\frac{1}{2}$  per cent. of phosphorus and getting to 0·5 per cent., but in getting from 0·5 per cent. to the desired point. Experience invariably and speedily enforced this lesson. That was the second point to be kept in view.

The question was, How far did the Kladno modifications bear on these points?

For working a charge under the same slag in a single furnace, it was clear that, after the bulk of the metalloids had been taken up and the oxide reduced to the required extent, they had to bring the slag—the whole of it—to the necessary condition to take up the difficult traces. Tapping the slag was not an easy matter; it was a “messy” business, and never complete and satisfactory; but supposing they could manage this fairly, they had, as had been stated in the discussion, to add fresh lime and oxide and lose heat. That, of course, might be hot or molten; but they wanted a fresh furnace more than a fresh slag, and that, he took it, was the pivot on which the whole thing turned. After the furnace has been driven at the highest possible heat for the roughing down, it was in the least suitable condition for the exact and more refined operation of finishing. A furnace in the best condition with the proper cinder must be of vital importance in the difficult refining stage, and instead of complicating must greatly simplify things.

Any accidental mixing, too, of any acid part of the structure of their furnace was, it must be remembered, a serious hindrance, especially near the end of the working of a basic charge. He

believed that the plan of transferring to a finishing furnace, though apparently a small matter, might have the most marked effect on the open-hearth basic process.

With regard to the difficulties that might arise through the duplication of furnaces, it was only fair to put against this the fact that they very considerably lightened the strain on the furnaces by dividing the working. He noted it was said at a meeting lately that working a charge eight hours in one furnace was the same as working a charge four hours each in two furnaces; but that was not correct. It was in the later stages of working in their long operations, and towards the end that melting plant suffered most.

That duplex plan of working and dividing into stages certainly appeared to bring the process more into the desired condition for obtaining the exact reactions and results that should be, above all things, aimed at in this refined process. The mechanical operation of pouring the metal on the cinder, as pointed out, was of considerable importance.

He hardly thought the mechanical question of transferring need be a serious obstacle. One of the largest steelworks for a considerable time had used a receiving ladle and poured into the casting ladle; this was a step further, and rather different, but not, he thought, more difficult.

He also thought it might be fairly expected that the often tried plan of using molten iron from the blast-furnace or cupola might, under these newer conditions, be found a success, as the great bulk of the charge might be run into the first furnace, having the cinder prepared to receive it.

Fifteen years ago he had ventured to express the opinion to Mr. Gilchrist that the basic process would find its largest adoption through the Siemens furnace, and he had not changed his mind during that time, but he did not anticipate quite fifteen years' delay.

Mr. E. BERTRAND, in reply to the discussion, sent the following communication:—From the practical experience gained, the property of reducing in the open-hearth metallic iron from its oxides must be considered an established fact for carbon, silicon, and phosphorus. How much metallic iron each pound or per cent. of

carbon, silicon, and phosphorus contained in the pig can theoretically reduce is, of course, a simple matter of calculation.

The question, however, here at issue is to what extent these reducing properties may be practically utilised in the open-hearth to reach the greatest possible increase of yield. Of course, this will depend on the more or less favourable conditions presented for this action in the course of the process; and it is obvious that, besides the proper degree of neutralisation of the silica and phosphoric anhydride resulting from the pig by adding the correct equivalent of ore and lime, it must be of the highest importance to interrupt the process, and to get rid of the phosphoric and silicious slags perfectly and at the right moment. This is the object of the combined work.

In finishing, these slags have, then, no influence whatever upon the work, which is certainly not the case when the heat is made and finished in one and the same furnace. And even if the slag be drawn off ever so carefully, enough of it will still remain to materially affect the finishing work and the final quality of the steel.

The silicon and phosphorus are, like the carbon, not only valuable as reductors, but they are also no doubt an indispensable auxiliary for increasing the heat of the bath to the necessary temperature.

Mr. Gilchrist's comparison of the primary and finishing furnaces with the old refinery and finery work illustrates the character of the work perfectly.

I can perfectly understand what causes Mr. Snelus to ask why it should appear desirable to get the phosphorus down as low as possible in the primary furnace, and find that my remark in this respect has not been fully understood.

The work in the primary furnace may certainly be overdone, and then a quantity of the iron lost by reoxidation that had been gained by reduction. It will, however, be an advantage to have a plant arranged so as to be able, under all circumstances, to run down the phosphorus as low as may be found desirable. Circumstances, and especially the nature and chemical composition of the pig to be worked, will practically regulate this question. The experience of the person in charge of the furnace will easily fix the most favourable moment for tapping the primary furnace.

For making hard steel for rails, &c., the metal is finished off with ferro-manganese in the usual way in the lower furnace, and the metal carbonised as it flows into the ladle.

In answering the remarks of Sir Lowthian Bell, I must concede that, having three metalloids, carbon, silicon, and phosphorus, with great affinity for oxygen, *i.e.* with great reducing properties, present in the bath, it is very difficult to say what really takes place, what part of the reducing work is due to each of these elements respectively, and we must be content with the fact that by their aid so much metallic iron has been gained from the ore, and a reduction of the costs thereby reached.

The reducing action of the silicon and phosphorus no doubt depend upon the perfect neutralisation of the resulting silica and phosphoric anhydride by addition of the proper quantity of lime, otherwise silicates and phosphates of iron would result from the oxidation of the silicon and phosphorus, thereby hindering the reduction of iron. The silicon and phosphorus are, as already indicated, also highly valuable for increasing the temperature of the bath. That a perfect reduction of all the iron contained in the ore, or in the slag, should take place, would no doubt be expecting too much; as even the most perfect steam-engine will never develop the full mechanical energy theoretically equivalent to the coal actually consumed.

Mr. James Riley's question, What is the use of two or three furnaces? may best be answered by another question, namely, What is the harm in running two or three furnaces together, provided that these three working together do more and better work than if each of them were working separately for themselves?

The practical advantages of the combined work are, as have been so far proved—

1. The possibility of working with any proportion of pig, or even with pig iron alone, and of then using an ordinary cheap phosphoric and siliceous pig, producing therefrom a steel of excellent quality and very low in phosphorus;

2. Materially increasing the yield of metal by reduction from the ore added;

3. Increasing the actual work done per furnace; *i.e.* three furnaces—two primary and one finishing—working together upon the combined plan, and using phosphoric pig, will, within

the same time, produce more steel than if the same three furnaces, charging the same metal, were working each one separately for itself.

I will concede that when working with very pure pig iron and scrap, the saving in cost will not be as great as when working with cheap phosphoric and siliceous pig; but the possibility of doing this, and producing therefrom steel of high quality, is certainly a fact presenting great commercial advantages.

I must further oppose the opinion of Mr. James Riley, that working in one furnace and then drawing off the obnoxious slags will do just as well, simply for the reason that, no matter however much care is taken, it is practically impossible to draw off all the slag perfectly from the bath in an open-hearth. By the great surface the bath presents, enough slag will under all circumstances remain in the furnace to materially affect the further progress, and especially the finishing of the heat. The damaging effect of the slags may be comparatively insignificant when the pig iron or the slags contain little or no phosphorus; but as the analysis shows slags containing 12 to 15 per cent. and more of phosphoric anhydride to deal with, then but a small quantity of slag left behind in the furnace is quite sufficient to greatly retard the finishing of the heat, and eventually to spoil the quality of the steel. This can never be the case when working upon the combined method, where the obnoxious slags are in all cases perfectly separated from the metal before finishing the heat.

Regarding the runners, there has been no difficulty whatever in their use, even when, as at Kladno, the pitch is not quite as steep as one would wish; and, further, the metal flowing down from the primary furnace is not at all pasty, but quite liquid and very hot (*vide* the paper of Mr. Gilchrist).

By a glance at the drawing (Plate XIII.) of a proposed plant of three furnaces—two primary and one finishing—to work together, it will be seen that the length of the troughs is not more than 36 feet, and, in my opinion, their use presents great advantages over the use of ladles, which is, however, also feasible.

Tapping one furnace into the other takes about three to four minutes, and costs a very insignificant amount of labour; also the cost of maintaining the runners is comparatively insignificant, and certainly much lower than the cost of maintaining ladles, not

to speak at all of all the gear and mechanical manipulation incident to their use.

Mr. Bernard Dawson's idea of the manipulation of tapping one furnace into the other is therefore quite wrong, and the engineering point of view speaks for the runners. The men when tapping do not throw down their tools and run from one furnace to the other, but the men at the upper furnace merely open the tapping-hole, the metal flows down, and the thing is done. I must here call attention to the fact that when working three furnaces separately, then *three* furnaces must be charged; while when working with three furnaces upon the combined method, only the two upper (primary) require men and labour for charging, the finishing furnace only needing the men necessary for its ordinary working.

When using runners, only a thin skin of metal remains in them after tapping, so that practically all the metal comes into the finishing furnace; while it is a well-known fact that a certain loss by splashing will always take place when the metal is poured over from one vessel to the other, as would be the case when using ladles. Further, the pouring over by means of ladles certainly involves much more time than the three or four minutes necessary for tapping the one furnace into the other, and it is therefore not certain if by the use of ladles a certain amount of skull will result which in the other case would take the shape of ingot steel.

These are all reasons that speak in favour of runners, and I would therefore for a new plant certainly advise this arrangement.

How far a ladle arrangement in connection with a travelling crane will practically serve the purpose is a question that can only be answered by actual experience. This will certainly depend upon the perfection of the whole arrangement, and especially upon the prompt and accurate action of the crane. Since, by pouring over from the ladle into the furnace, metal is apt to be lost by splashing, I would in that case propose the use of a ladle that may be tapped at the bottom, so that the metal flows through a spout into the finishing furnace. (See Plate XIII.)

The ladle arrangement, if practically successful, certainly presents the great advantage that not only old existing plants may be adapted, but that the whole furnace plant is not all dependent

upon the groups or number of furnaces forming a group, since in that case any furnace suitable may be used either as primary or as finishing furnace.

With reference to the questions of Mr. Bernard Dawson and Mr. J. W. Spencer regarding the cost of plant and of maintenance, further of the cost of the process compared with the ordinary method, I beg leave to remark I have in my paper been particularly careful to communicate nothing but absolutely established facts, and to avoid all speculation that is not based upon absolute figures, that, especially regarding the working with phosphoric pig iron alone, can at the best be approximate guesswork. That, however, the cost of working by the new method will not be higher but lower, naturally follows from the statements I have already made.

In the same way, referring to my plan of a proposed plant of three furnaces—two primary and one finishing—it must be plain that, excepting the cost for the platforms in two different elevations, the cost of a plant of this kind cannot be materially higher than when furnaces of the same dimensions are arranged in the ordinary way.

The advantage pointed out by Mr. J. E. Stead, of making steel from ordinary Cleveland pig No. 3 or 4, or practically any ordinary pig sufficiently low in sulphur, is probably for England the one presenting the greatest practical value; but this only when the primary furnace is also basic lined, and the metal not only desiliconised, but also to a great extent dephosphorised, so that in finishing only the carbon and the small remainder of phosphorus are to be eliminated. A certain part of the silicon contained in the pig will certainly already be oxidised during the melting, and the silicon thus oxidised can, of course, not effect the reduction of metal from the oxides of iron, for this effect can only be expected from the metalloids contained in the bath when it is molten and in a liquid state. The quicker the metal is molten the more silicon will be left in it to assist in the reduction of metallic iron, and there can therefore be no doubt that the reduction of metal will be the greater the less the metalloids have been oxidised during the melting of the pig.

From this it follows, further, that the best results, as far as the increase of yield is concerned, should be gained when the metal

need not be melted at all, *i.e.* when liquid pig metal is charged into the furnaces.

This would, of course, present also other great advantages, such as a great increase of output, saving of fuel, labour for charging, since the metal need only be poured into the furnaces, &c.

Based upon the above reflections, I am convinced that this working with liquid pig metal will produce far better results than have been so far gained, and I therefore agree with Mr. Harbord's remarks regarding this point, which are also sustained by Sir Lowthian Bell's experiment of running liquid pig metal through molten oxide.

This direct working with liquid pig metal has, it must be conceded, not yet been practically tried, but there is really no reason why it should not work perfectly, or present any practical difficulties.

The explanation of Mr. Windsor Richards regarding the use and value of the second furnace exactly hits the point, and the idea of getting the pig down to an extremely low percentage by the aid of the second (finishing) furnace was indeed the motive that first prompted us to try the combined method of working. It is indeed, as Mr. Richards remarks, quite easy to get the phosphorus in the metal down from a high percentage to a certain point, but it is quite impossible to reach a very low percentage of phosphorus with certainty in the presence of a highly phosphoric and eventually siliceous slag. And even when, under these circumstances, the phosphorus is reduced to a comparatively low standard, the danger of rephosphorisation is great when ferro-manganese is added to the metal.

This is all avoided by the use of the second furnace, where the obnoxious slag is perfectly eliminated and a new slag low in phosphorus formed, so that a very low percentage of phosphorus may be easily reached with certainty in the finished steel.

The idea expressed by Mr. Windsor Richards, to utilise the more or less phosphoric ores, that is, the pig iron resulting therefrom in Cleveland, Lincolnshire, and Northamptonshire, has been also the main object of my paper, and the chief reason which has prompted me to lay this matter before British metallurgists.

Mr. Snelus' remark, that it would be better to keep the silicon in the slag lower, is no doubt theoretically correct. It must

certainly be done when working only with one furnace. This, however, means that either the use of a siliceous pig iron must be avoided, or that, in case it is used, a still greater excess of lime must be added to neutralise the silicon; and it is just the great advantage of the combined method that a more or less siliceous pig iron may be used and the silicon eliminated without the necessity of adding a great excess of lime.

That the phosphorus goes out of the metal to a certain extent, even when a large amount of silicon is present in the slag, is proved by the analysis of the metal from the primary furnace. On the other hand, it is also true that a very low percentage of phosphorus in the finished steel can only be reached when the silicon is already eliminated and the slag excessively basic, as is the case in the finishing furnace.

To the remarks of the President I beg leave to reply that the preliminary work of desiliconising may certainly also be done by means of a converter; but there can be hardly any doubt that this may be done in a far simpler and cheaper way by means of an open-hearth, the plant also costing less.

The work done in a basic open-hearth further presents the great advantage that a very great part of the phosphorus is removed at the same time.

In conclusion, I beg leave to offer my sincere thanks to those gentlemen who have taken part in the discussion, and who have thereby afforded me the opportunity for a more perfect explanation of the subject.

Further, I must sincerely thank Mr. Bennett H. Brough and Mr. Gilchrist for all their kindness and care in behalf of my paper, which I value all the more owing to my inability to personally attend the meeting.

On the motion of the PRESIDENT, a vote of thanks was accorded Mr. Bertrand, and the following papers were read :—

## MALLEABLE CAST IRON.

BY GEORGE PARKER ROYSTON (SHEFFIELD ASSOCIATE), BOWEN SCHOLAR,  
MASON COLLEGE, BIRMINGHAM.

THIS paper contains an account of the investigation carried out by the author on the manufacture of malleable cast iron.

### HISTORICAL NOTE.

The making of malleable castings in iron appears to have been first carried out about two hundred years ago. The earliest mention of it is found in a treatise published in the year 1722, and entitled *L'Art d'Addoucir le Fer Fondu*. It contains an account of the work done by the author, Reaumur, the distinguished French savant, in this field; and his description of the process is almost identical with that of the method employed to-day in and around Birmingham. Whether Reaumur was the first to be aware of the action of the various oxidising agents is not quite clear; but as he introduced this manufacture into France, and as it is not known to have been used in England at this time, it is reasonable to ascribe to him the credit of the invention.

In 1804 a patent was granted to Samuel Lucas, of Sheffield, for the working of this process in England. Previous to this many attempts were made to soften iron castings by Englishmen.

In 1769, Joseph Ashton of Birmingham obtained a patent for the softening of cast iron by heating in a slow fire for the manufacture of nails.

Again in 1783, George Mathews, of Broseley, patented the same process for use in the making of cannon, anchors, chains, rollers, and forge-hammers; he says, "when annealed the articles were as malleable and tough as hammered or wrought iron." This process differs from Reaumur's in that the carbon is not abstracted from the iron, but changed from the combined to the graphitic form. The finished material generally goes under the name of "black-heart" iron.

The patent list contains another interesting specification, which was filed in 1852 by Jean Ernest Beauvalet. He softened cast iron bars and made them into malleable iron by heating them in a cementation furnace with oxides of iron, manganese, copper, and zinc. The bars were made into steel by only partially effecting the oxidation of the carbon, and a uniformity of composition was obtained by heating them subsequently with charcoal.

Castings of grey iron, especially when of small size, are brittle, owing to the graphite plates, which form planes of weakness. Wrought iron, owing to its high melting-point, is not adapted for use in castings, except by some method analogous to the *Mitis* process.

Before Reaumur instituted his process, the use of iron was not possible for making malleable articles of intricate shape by casting. Beautiful work has been done in the olden days, when labour was somewhat cheaper, by forging the wrought iron into shape; but the value of the articles must have been almost as great as if cast in the costlier but more easily meltalbe metals—copper, silver, and gold.

The introduction of this process marked a new era in the history of commerce, by making possible the cheap production of many articles which are almost necessary to civilisation.

#### PART I.—WORKS PROCEDURE.

By the kind permission of Mr. Thomas Francis, the author had the opportunity of studying the process at the works of Messrs. Thomas Francis & Co., at Sparkbrook, Birmingham.

This firm is one of the oldest manufacturers of this material, a good example of their work being shown at the exhibition illustrative of local industries (see this Journal, 1895, ii. 338), held at Mason College, when the Institute visited Birmingham two years ago.

Tests of the materials and produce were taken for chemical, mechanical, and microscopical examination.

The works procedure was as follows:—White refined haematite iron was melted in a crucible furnace, the crucible being closed with a lid. The latter is of great use to prevent absorption by

the iron of sulphur from the coke and gases. The molten metal was poured into the moulds prepared in greensand. There is little difference from ordinary foundry practice observed. The shrinkage of white iron runs about  $\frac{1}{4}$  inch to the foot, but as the annealing causes an expansion of  $\frac{1}{2}$  inch, this brings the allowance to the same as that allowed for grey iron. The adhering sand was removed by shaking in a revolving barrel. The bars were then ready for annealing, and were carefully packed with other work in the annealing mixture. This is raw haematite iron ore mixed with "spent" or burnt iron ore—that is, ore which has previously been used, and has lost a considerable portion of its oxygen. The proportion is three or four of the spent to one of the raw ore, according to the size of the articles annealed. Great care is required in packing, to prevent the bars from touching each other, and from warping or losing their shape, the ore having to be placed all round, as well as in the crevices or hollows of the castings. The ore was ground to about the size of a pea. The whole was contained in cast iron pots, which in this case were 26 inches high and 15 inches diameter, and provided with lids, the latter being luted on. These pans, owing to the scaling action to which they are subjected, only last about six or seven heats. It is necessary that they should not soften during the heating or by the annealing, and therefore the iron of which they were made was white iron and contained manganese. The pots, being now luted up, were placed in the furnace or oven in which the annealing takes place. The one used in this case was a rectangular structure having a fire-hole at each corner about 9 inches below the floor-level. The flames enter on the floor-level, and passing towards the middle, are drawn out at the roof, the flue running down the centre. This arrangement produces a uniform temperature. The draught is so controlled that the maximum temperature attainable shall be lower than the melting-point of white iron. The furnace was 10 feet  $\times$  13 feet and 5 feet high, and held about sixty pots. These weigh when charged 3 cwt. each, but the ore and pots themselves weigh only  $2\frac{1}{2}$  cwt., whilst the metal which is being annealed weighs only  $\frac{3}{4}$  cwt.

The pots were placed two-high in the furnace, the charging being effected by means of long-armed bogies, while the furnace was black-hot, it having only just been emptied. The door was

now luted up and firing commenced. This was continued for seven days. A record was taken of the temperature during this period by means of a Le Chatelier pyrometer, the wires of which were insulated well, excepting at the couple-end, and inserted in the annealing pot. By the second day the temperature was 750° C., and this on the third was increased to 860°, the latter temperature being maintained during the next three days with a variation of 40° (from 860° to 900° C.). The firing was now somewhat lessened, the temperature gradually falling to 800°, and on the seventh and last day to 680°, when the furnace was emptied. The coal used amounted to 4 tons, which works out to 1 ton 16 cwts. of coal being required for the treatment of each ton of metal. It was noticed that as the pots got red-hot copious jets of gas were emitted and burnt with a blue flame.

The pots were allowed to cool, and having been emptied, the bars were found to be covered with adhering grains of ore. This was now removed by vigorous shaking in the revolving barrel with pieces of hard scrap and other suitable material. The bars were now malleable cast iron.

#### CHEMICAL ANALYSES.

From the microscopic examination it was seen that the iron after annealing was of a composite structure. It was made up of four different layers or rings of material. The drillings for analysis were therefore taken in two ways. Either drillings were taken from each layer separately; or else, in order to obtain "an average," the drill was taken right through the bar and the whole sample thus obtained was used for the estimation.

No.	Graph. C.	Comb. C.	Si.	S.	P.	Mn.
1	0·61	3·33	0·61	0·081	0·044	0·112
2	0·19	3·69	0·565	0·058	0·045	0·043
3	...	...	...	0·096	...	...
4	...	...	...	0·161	...	...
5	...	...	...	1·600	...	...
6	...	trace	0·57	0·057	0·045	0·043
7	...	0·51	0·57	0·057	0·045	0·043
8	0·38	0·90	0·56	0·057	0·045	0·043
9	2·88	1·40	0·57	0·057	0·045	0·043
10	1·56	0·74	0·57	0·057	0·045	0·043

No. 1 is the original pig-iron : "Lorn" Refined Haematite.

No. 2 pig as cast into test-piece.

No. 3 is No. 2 melted in open crucible.

No. 4 is the same melted in cupola.

No. 5 is the coke used.

No. 3, 4, and 5 illustrate the absorption of sulphur by the iron.

No. 6 is the outside layer of annealed bar. The silicon is mostly present as silica.

No. 7 is the second layer.

No. 8 is the third layer.

No. 9 is the centre of bar, or fourth area.

No. 10 is average analysis of the whole section.

	11.	12.
Fe <sub>2</sub> O <sub>3</sub> . . . . .	80·14	35·10
FeO . . . . .	...	46·81
Al <sub>2</sub> O <sub>3</sub> . . . . .	0·14	0·19
MnO . . . . .	0·64	0·62
CaO . . . . .	0·428	0·37
SiO <sub>2</sub> . . . . .	16·620	16·64
S . . . . .	0·026	0·028
P . . . . .	0·022	0·020
H <sub>2</sub> O . . . . .	0·320	...
Loss on ignition . . . . .	1·320	...
Metallic iron . . . . .	56·10	60·98
	14.	15.
Fe . . . . .	88·04	91·62
SiO <sub>2</sub> . . . . .	1·80	...
P . . . . .	0·025	...
S . . . . .	0·028	...
MnO . . . . .	0·660	...

No. 11 = Raw Ulverstone haematite ore.

No. 12 = The same after use in annealing.

No. 14 = Pellets from the "spent" ore.

No. 15 = Pellets from the "spent" ore.

*Remarks on the Analyses.*—It will be noticed that the iron used is practically free from manganese. This is necessary, as manganese, if present in the iron in appreciable quantity, prevents the annealing process taking effect.

The change taking place on annealing is twofold. On the outside oxidation is found to have occurred, whilst in the centre the combined carbon is changed to graphite.

The only other element affected appears to be the silicon, which in the outer ring is oxidised to silica.

The action on the ore used in annealing is strongly reducing. Some pellets were almost malleable, and showed only about 6 per cent. of oxygen remaining.

## MECHANICAL TESTS.

*Bending Tests.* $\frac{1}{2}'' \times 1'' \times 14''$ .

White iron of course did not bend. Annealed bars bent to half-circle and fractured.

*Tensile Tests.*

	1.	2.	3.	4.
Breaking stress, square inches .	7.88	7.01	20.70	20.00
Elongation on 6 inches . . . .	...	...	1.60	2.01
Contraction of area . . . .	...	...	2.90	4.02

No. 1 = White iron. Sound and platelike fracture.

No. 2 = White iron. Sound and platelike fracture.

No. 3 = Annealed bar. Shows threefold structure.

No. 4 = Annealed bar. Shows threefold structure.

*Remarks on the Tests.*—Bends are about the average for this class of material. Where any graphite is left in the iron, it fails to bend to double.

Tensile tests are good. The fracture only shows three different materials. These correspond to the analysis as follows:—

(1st.) Grey fibrous, outside corresponding to the 1st and 2nd layers, shown by chemical and microscopic analysis.

(2nd.) Grey crystalline, structure identical with the 3rd layer of the micro-section.

(3rd or centre.) Sometimes brown plates and at others black fibrous material representing the 4th layer or centre of the micro-section.

## MICROSCOPIC RESULTS.

On etching a section of the bar, it was seen that three layers of different materials were present. Examined under the microscope, the outer band was again shown to be composite, and the bar was thus found to contain four different materials. The first and second layers, counting from the edge, are not sharply defined, as are the third and fourth. These sections may be described as follows:—

(1.) *White iron.*—This contains only two minerals—pearly compound and mass cementite. They are present in just about equal proportions. The two go together to build up feathery crystals. The pearly compound striæ are but faintly discernible.

(2.) *Annealed bars*.—Fourfold structure. For purposes of reference the author will refer to these layers as A, B, C, and D; the last named being the centre, and A the outer layer.

*A.* This is composed of crystals of iron. Between the crystals there are discernible small shining particles of silica or quartz. The iron crystals mostly etch dark with nitric acid, and the author has found a considerable amount of oxygen to be present in the iron.

*B.* Composed of crystals of iron and crystals of pearly compound. The proportions vary from the outside edge, which is nearly all iron, to the inner, which is nearly all pearly compound.

*C.* All pearly compound crystals. These are sharply defined from D.

*D.* Mass cementite and crystallised iron. The latter is impregnated with graphite, which is sometimes finely divided, sometimes occurs in the form of rounded masses, and at other times has a wormlike appearance.

## PART II.—EXPERIMENTS ON ANNEALING.

Bars were placed in various substances in place of the ordinary mixture of ore, the annealing being for the customary length of time and at the usual temperature.

Other bars were placed in the ordinary mixture, but given three consecutive annealings.

## CHEMICAL ANALYSES.

These were made on average drillings of the whole section of the bar. As the carbon is the only material which is capable of being removed during the annealing, the proportions of the other elements present in the iron are not here recorded.

No.	Graph. Car. Per Cent.	Comb. Car. Per Cent.
16 . . . . . . . .	0·19	3·69
17 . . . . . . . .	0·36	0·73
18 . . . . . . . .	0·49	0·58
19 . . . . . . . .	1·79	0·64
20 . . . . . . . .	1·75	0·63
21 . . . . . . . .	1·60	0·68
22 . . . . . . . .	2·30	0·81
23 . . . . . . . .	2·73	0·99
24 . . . . . . . .	2·80	0·94
25 . . . . . . . .	nil	trace

- No. 16 is the white iron bar.  
 Nos. 17 and 18 were immersed in raw haematite and limestone respectively.  
 Nos. 19, 20, 21 were packed in lime, sand, and bone-ash. The pots were left open to allow for diffusion of the atmospheric air.  
 No. 22 was heated in wrought-iron drillings, the pot being luted.  
 Nos. 23 and 24 were packed in grey cast iron drillings and charcoal, the lids being luted on.  
 Bar No. 25 was annealed thrice over to eliminate the whole of the carbon. The mixture was 3 of spent ore to 1 of raw.

### MECHANICAL TESTS.

#### *Bending Tests (2" radius).*

No.	Angle of Bend.	Size, Inches.
16	nil.	14 x 1 x $\frac{3}{8}$
17	80°	14 x $\frac{1}{4}$ x $\frac{3}{4}$
18	90°	14 x $\frac{1}{4}$ x $\frac{3}{4}$
19	75°	14 x 1 x $\frac{3}{8}$
20	75°	14 x 1 x $\frac{3}{8}$
21	75°	14 x 1 x $\frac{3}{8}$
22	10°	14 x 1 x $\frac{3}{8}$
23	nil.	14 x 1 x $\frac{3}{8}$
24	nil.	14 x 1 x $\frac{3}{8}$
25	{ 180° without } fracture }	14 x 1 x $\frac{3}{8}$

All the bars were the same size before annealing, but the scaling action of the limestone and raw haematite in Nos. 18 and 17 greatly reduced the dimensions of these bars. The scale was, of course, removed in the tumbling barrel.

#### *Tensile Tests.*

No.	Tons per Square Inch.	Elong., Six Inches.	Reduction of Area.
16	7.80	nil.	[nil.
17	16.30	4.60	2.10
18	15.40	5.60	3.10
19	19.80	1.90	3.15
20	18.40	2.10	2.10
21	20.10	2.20	3.05
22	22.20	nil.	nil.
23	14.10	"	"
24	13.95	"	"
25	16.60	10.80	7.96

### MICROSCOPICAL ANALYSES.

Bar No. 16 has been already described.  
 Bars 19, 20, and 21 were exactly like those annealed in the normal mixture.

Bars Nos. 23 and 24 were of one uniform material, being composed throughout of the same minerals as those found in the centre (D, see above) of the normally annealed bars.

No. 25 was composed entirely of iron crystals, with the oxidised silicon lying between the facets as in A.

No. 22 contained three layers of different materials, viz., B, C, and D.

Nos. 17 and 18 were made up of three layers, A, B, and C.

*Remarks.*—The strong action of raw haematite and limestone was evidenced before the chemical analyses were made by the scale, with which they were covered to the extent of  $\frac{1}{16}$  inch thick.

No action would have taken place in 19, 20, and 21 had the pots been luted up. To allow the atmosphere to diffuse in, the pots were left open. Sand, lime, and bone-ash have not the power to oxidise the carbon in the iron, the purposes which they serve being to dilute the atmosphere, and to prevent the castings from being deformed and "falling" in the pots.

No. 22 was interesting. The elimination of carbon had not proceeded by oxidation, but from diffusion of the carbon from the white iron into the wrought iron.

No carbon had disappeared from the bars heated in charcoal or in cast iron turnings. These, therefore, had the same structure as the interior of the partially oxidised bars. Had the cooling from  $800^{\circ}$  C. been slower and more regular, they would have contained no mass cementite, as all of it would have been decomposed into iron crystals and graphite. Had this been carried out the iron would then have become "black-heart." "Black-heart" castings are not manufactured to any great extent in England, but meet with a large demand in the United States. They possess all the properties required in malleable castings, and can be made of a larger size and in a shorter time than the "ordinary" or Reaumur iron. The process of manufacture is to anneal the iron out of an oxidising environment, heating to about  $850^{\circ}$ , and slowly cooling to a temperature below  $AR_1$  or  $660^{\circ}$  C. Owing to the graphite present no bend can be obtained from this material.

The same effect can be obtained, no matter what the iron be

packed in, so long as oxidation of the bar is prevented. A bar heated in lime with the pot carefully luted up gave the same result as bars Nos. 23 and 24.

#### GENERAL SUMMARY OF RESULTS.

The hard brittle white iron castings may be softened and annealed in two ways, either by oxidising the carbon, or by changing it from the combined to the free or graphitic state. The former and older method, the one used and described by Reaumur in 1722, is that most generally followed. This is generally effected by heating in oxide of iron at a bright red heat for a considerable period, dependent on the thickness of the bar to be annealed. It may also be placed in lime, sand, or bone-ash, in lieu of oxide of iron, providing the atmosphere be used as a source of oxygen. It is necessary that the iron be free from manganese and sulphur, or the elimination of the carbon will be delayed. The reaction taking place between the carbon and oxygen should be  $C + O = CO$ . Should it be  $C + O_2 = CO_2$ , the iron will also be oxidised by the carbonic acid, and the castings will be scaled. When oxides of iron are used as a source of oxygen, the carbon monoxide partially reduces the iron of the oxide to the metallic state. This process must necessarily be of long duration owing to the carbon having to travel from the interior to the outside of the bar to be oxidised. The diffusion of the carbon takes place in the iron, as in other solutions, and the hotter the iron is the quicker will the diffusion take place. A limit to the oxidation of carbon at the higher temperatures comes into play owing to the danger of deforming the castings. The temperature must be below  $1000^{\circ} C.$  for this reason. The carbon not being in solution below  $660^{\circ} C.$ , no oxidation can be effected without oxidising the iron along with the carbon. The quickest result of the diffusion and oxidation of the carbon in white iron obtained by the author was the following:—A bar  $\frac{3}{8}$  inch diameter heated to  $900^{\circ} C.$  required twenty-two hours to complete the reaction.

The second method of annealing white iron, viz., by decomposing the carbide into graphite and free iron, is effected by more or less continued heating between  $850^{\circ}$  and  $650^{\circ} C.$

This occurs more or less accidentally, owing to the slow cooling of large masses in the Reaumur process, if the carbon be not already abstracted completely. The rationale of this process is explained in the author's paper on "The Relation of Carbon to Iron at High Temperatures," submitted to this meeting.

Iron castings produced by this method are quite as soft as those obtained by the Reaumur method, but owing to the graphite present no bend can be obtained. There is no limit to the size of the castings produced by this method, a large piece taking quite as short a time as those of smaller size. The quickest results obtained by the author was the annealing of a piece in five hours only, 0·6 per cent. out of a total of 3·8 of the carbon remaining in combination with the iron.

Another method of softening white iron, not previously described, has been discovered by the author. The castings are carefully packed in some non-oxidising material and heated to the temperature at which the iron would solidify after fusion, this temperature being about 35° C. below the melting-point of the metal. As a result of this treatment, the white iron becomes changed into a steel containing 1·5 per cent. of combined carbon, the remainder of the carbon being distributed through the metal in the form of finely divided graphite. The effect is practically instantaneous as soon as the correct temperature is reached. Care must be taken, however, not to raise the temperature too high, or otherwise the iron would be melted; by careful manipulation the operation may be performed without so much as a rounding of any sharp corners on the casting.

The change will not occur if the iron contain any appreciable quantities of manganese, tin, or chromium, but the presence of silicon, aluminium, or nickel has no adverse influence.

As a practical result of these experiments, it is now possible to accomplish in a few hours an operation which has previously required as many days. Indeed, a steely material may even be obtained by merely heating the white iron up to a somewhat higher temperature than that usually employed, the change being practically instantaneous.

And further, the experiments tend to show the probability of a complete softening effect, that is, the production of malleable iron, being attained with the same speed as in the case of the

harder or steely material above referred to. The author's attention is at present being given to this matter.

The author desires to place on record his high appreciation of the generosity of Mr. Thomas Francis in allowing him to make the great number of large-scale experiments required in this research at his works. He will also take this opportunity of thanking Mr. C. Francis for his assistance in the carrying out of those experiments which were conducted at the works.

## THE RELATION OF CARBON TO IRON AT HIGH TEMPERATURES.

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AT an early stage in the author's research on the annealing of white cast iron, communicated in a separate paper, entitled "Malleable Cast Iron," it became evident that no satisfactory solution of the problem as to the precise influences operating either in the oxidation or decomposition processes there alluded to would be obtained unless the precise relations of the carbon and the iron in these alloys were known.

In the first place, it was necessary to ascertain both the temperatures at which the formation of graphite occurred and the various ways in which this formation was brought about. To arrive at this the following experiments were made :—

### I.—*Precipitation of Graphite in Molten White Iron, or on the Solidification thereof, by the addition of a Third Element.*

It is well known that aluminium and silicon favour the precipitation of graphite. Further experiments made by the author, and still in progress, have shown that nickel is in this respect almost as effective as silicon. Tin, manganese, sulphur, and chromium tend in the opposite direction.

### II.—*The Action of Gases on the Solidified Metal.*

Nitrogen, hydrogen, carbon monoxide, carbon dioxide, coal-gas, and ammonia vapour were prepared and passed separately over samples of white iron heated to 900° C. for a period of twelve hours. In every case a negative result was obtained, all the carbon remaining in the combined form. The iron used was the same as in the last experiment, and had the same composition

as the white iron bars used in the annealing experiments quoted in the other paper.\*

### III.—*The Influence of Varying Temperatures on White Iron.*

The iron used in this series of experiments was Swedish white iron, containing practically all its carbon in the combined form, the analysis being as follows:—

	Per Cent.
Carbon (combined) . . . . .	3·85
,, (graphitic) . . . . .	trace
Silicon . . . . .	0·29
Phosphorus . . . . .	0·02
Sulphur . . . . .	0·03
Manganese . . . . .	0·15

*Experiment 3 (a).*—Bars were heated for prolonged periods (ranging from twelve hours to a week) to temperatures not exceeding 670° C.; but in no case was there any evidence of graphite being formed.

Other bars were then heated to temperatures varying from 760° to 1000° C.; and here again no graphite was ever produced.

*Experiment 3 (b).*—Bars of white iron which had a melting-point of 1065° C., and a solidifying-point of 1030° C., were raised rapidly to the latter temperature (1030° C.), and were then at once allowed to cool. The bars, after this treatment, were found to be comparatively soft, and could be easily filed or drilled; they contained the greater portion of their carbon in the form of graphite, as indicated by the following analysis:—

	Before Heating.	After Heating.
Combined carbon . . . . .	3·85	1·50
Graphitic carbon . . . . .	trace	2·30

Metallographically, micro-sections of the treated bars showed that they were composed mainly of crystals of pearly compound

\* This analysis was as follows:—

	Per Cent.
Carbon (combined) . . . . .	3·69
,, (graphitic) . . . . .	0·19
Silicon . . . . .	0·56
Sulphur . . . . .	0·058
Phosphorus . . . . .	0·045
Manganese . . . . .	0·048

(pearlite). These crystals were cemented together with mass-cementite. Graphite was present in considerable quantity.

These experiments were repeated several times, and always with the same results, both chemical and metallographic.

*Experiment 3 (c).*—A bar that had been softened by the method described in Experiment 3 (b) was melted and poured into a strip-mould. On examination, the resulting bar was found (as had been anticipated) to have become white iron again, and all the carbon had assumed the combined state.

*Experiment 3 (d).*—White iron was melted, poured into the form of a bar, which was removed from the mould at the moment of solidification, and was at once struck a few times with a hammer. Graphite was now found to be present, and the bar was identical, both chemically and microscopically, with those produced in Experiment 3 (b). It had, in fact, practically become a steel containing 1·5 per cent. of combined carbon; unfortunately the remaining 2·35 per cent. of carbon was of necessity distributed through the bar in the form of graphite, so that the metal was more or less brittle under shock and non-ductile.

*Experiment 3 (e).*—A bar of white iron was raised to a temperature of 1080° C. as in Experiment 3 (b), and was at once quenched in water. The bar was now intensely hard, but still contained much graphite:—

	Before Heating.	After Heating and Quenching.
Combined carbon . . . . .	3·85	1·50
Graphitic carbon . . . . .	trace	2·35

The carbon in the quenched sample behaved like that in hardened steel on the application of the Eggertz test.

The microscope showed the presence of graphite on a white ground, consisting of an intensely hard and somewhat brilliant "mineral," which exhibited no trace of structure even under a magnification of 860 diameters. In point of brilliancy this constituent was inferior to cementite, and in its properties it was half-way between this latter material and Arnold's "sub-carbide."

*Experiment 3 (f).*—A white iron was next melted, and while still fluid was poured into cold water; the quenching effect was not, however, instantaneous, as a bright white glow was perceived

on the metal for several seconds after pouring. But having once cooled to a temperature corresponding to about 1000° C., the subsequent cooling was practically instantaneous.

The micro-structure of the original white iron showed feathery crystals of cementite intermixed with pearly compound; but after quenching the pearlite was found to have been replaced by the material described in Experiment 3 (*e*), the feathery crystals, however, which still remained showed no change to have taken place in the cementite.

*Experiment 3 (g).*—Experiment 3 (*b*) was repeated, but the metal was this time heated *in vacuo*. The same results were obtained as before.

*Experiment 3 (h).*—An iron was so made by melting together Swedish bar and Swedish pig that it should contain 2·5 per cent. of carbon entirely in the combined form. On treating this bar under the conditions of Experiment 3 (*b*), the same results were obtained, only the graphite was present to the extent of 1 per cent. instead of 2·35 per cent., while the percentage of combined carbon was practically the same as in the previous experiment (1·5 per cent.).

*Experiment 3 (i).*—The previous experiments were tried at 1030° C. or above. The following show the result of treatment between 670° and 780° C.:—

A bar of white iron was heated to about 850° C., and was then slowly cooled (during about eight hours) from 780° to 670° C. In this case the bar was found to be much softer than those obtained in the previous experiments, and to contain a larger proportion of graphite:—

	Before Heating.	After Heating.
Combined carbon :	3·85	1·1
Graphitic carbon :	trace	2·75

Metallographic examination of the bar showed that graphite was present; but no pearly compound was found, and a part of the cementite originally present had disappeared. Iron crystals (ferrite) had taken the place of the pearlite, and of the missing cementite.

Although the iron still contained 1·1 per cent. of combined carbon, it was exceedingly soft. Cementite in mass, when embedded in iron crystals, would not, therefore, appear to exert the

strengthening and hardening effect that it does when present in the form of the well-known microscopic striae of the pearly compound.

*Experiment 3 (j).*—A bar slowly cooled from bright redness to 710° C., and taken out of the furnace, was found to be practically the same as that from Experiment 3 (i).

*Experiment 3 (k).*—A bar was similarly removed at 740° C., after prolonged cooling, with the following result:—

	Before Heating.	After Heating.
Combined carbon . . . . .	3·85	3·05
Graphitic carbon . . . . .	trace	0·80

In this case the micro-section showed cementite, graphite, pearly compound, and iron crystals.

It is thus evident that the decomposition of the cementite had begun but not proceeded far.

*Experiment 3 (l).*—Two bars, one of white iron and one of steel containing 0·9 per cent. of carbon, were heated to bright redness, the former for eight hours, and the latter for one hour; both bars were then slowly cooled together to 720° C., when they were removed from the furnace and quenched. The steel was intensely hard, but the iron was quite soft. The carbon distribution was as follows:—

Substance.	White Iron.		Steel.	
	Before Heating.	After Heating.	Before Heating.	After Heating.
Combined carbon . . . . .	3·85	1·20	0·90	0·90
Graphitic carbon . . . . .	trace	2·65	nil	nil

The micro-section of the steel exhibited the characteristic appearance of Arnold's sub-carbide. The white iron contained cementite, graphite, and ferrite, but no pearlite or sub-carbide was present.

*Experiment 3 (m).*—It has been shown that the rolling of steel at a dull red heat, when the carbon is present in the proportion of 1·5 per cent., has the effect of causing a precipitation

of graphite. The author found that hammering brought about the same result. White iron, however, on account of its brittleness, is unable to withstand the shock, and is broken up under the hammer.

A white iron bar treated as in Experiment 3 (b) received a vigorous hammering at this temperature, and the resulting material was found to contain 0·7 per cent. of combined carbon and 3·15 per cent. of graphite. The micro-structure showed pearly compound, graphite, and iron crystals. The bar was thus changed from a white iron containing 3·8 per cent. of combined carbon within a period of thirty minutes from the commencement of the heating.

#### *IV.—The Solubility of Carbon in Iron at Various Temperatures.*

*Experiment 4 (a).*—A bar of malleable cast iron in which the decomposition of the carbide was complete after treatment by the black-heart process (*vide paper on "Malleable Cast Iron"*) was heated to 620° C. for three hours. No change, however, was found to have taken place, the whole of the carbon being still present as graphite.

*Experiment 4 (b).*—A similar bar was heated for a like period to 720° C., and was then found to have taken up carbon from the graphite, as shown by the following numbers:—

	Before Treatment.	After Treatment.
Graphitic carbon . . . . .	3·5	2·65
Combined carbon . . . . .	trace	0·85

*Experiment 4 (c).*—A third bar was heated to 1030° C., with the result that a larger proportion of carbon was combined with the iron:—

	Before Treatment.	After Treatment.
Graphitic carbon . . . . .	3·5	2·0
Combined carbon . . . . .	trace	1·5

This material, after treatment, showed a micro-structure exactly similar to that obtained in Experiment 3 (b).

*Experiment 4 (d).*—Another piece of the malleable cast iron

was melted and poured into a bar, in which the whole of the carbon was found to exist in the combined state, the iron being white.

	Before Melting.	After Melting. trace
Graphitic carbon . . . . .	3·5	
Combined carbon . . . . .	trace	3·5

#### V.—Diffusion of Carbon in Iron.

*Experiment 5 (a).*—A steel containing 0·95 per cent. of carbon was heated to 900° C. in a porcelain tube *in vacuo* for twelve hours.

The weight after heating was found to be practically the same as before treatment, as will be seen from the figures quoted below. Two pieces of steel containing 0·15 per cent. of carbon were now placed in the tube along with the former sample, but not in contact with it. All three pieces were now heated to 900° C. for twelve hours, and after cooling *in vacuo*, were found to have suffered practically no alteration in the percentage of carbon or in weight. The initial weight of the 0·95 per cent. carbon steel was 20·208 grms., and after being thus heated for twenty-four hours it weighed 20·2052 grms.

The specimen containing the higher percentage of carbon was now placed between the other two and in contact with them, and the three were again heated under the same condition as before. On cooling, the centre piece was found to weigh 20·0998 grms., and thus to have lost 0·1054 grm., while the two low-carbon specimens had increased in weight by the same amount. Analysis showed that the carbon in the centre sample had been reduced from 0·95 per cent. to 0·42 per cent., while that in the outer bars had increased from 0·15 per cent. to 0·29 per cent. The amount of carbon which the centre bar had lost corresponded exactly with the loss of weight in the bar itself, whilst the outer bars were found to have gained in proportion. The actual figures are as follows:—

#### Low Carbon Bars.

	Weight. Grams.	Carbon Contents. Per Cent.
Before heating . . . . .	69·2856	0·15
After heating alone . . . . .	69·2860	0·15
After heating with 0·95 bar . . . . .	69·3840	0·29
Increase . . . . .	0·099	0·14
Increase of weight per cent. . . . .	0·143	0·14

*High Carbon Bars.*

	Weight. Grams.	Carbon Contents. Per Cent.
Before heating . . . . .	20.208	0.95
After heating alone . . . . .	20.2052 {	0.93 {
After heating between 0.15 carbon bars . . . . .	20.0998 }	0.42 }
Loss . . . . .	0.1064	0.51
	= 0.525 per cent. of gross weight of bar.	

The 0.15 per cent. carbon bars took up 95 per cent. of the loss of the 0.950 per cent. carbon bars.

It thus appears that the carbon, *but only the carbon*, had diffused to the outer pieces. These experiments appear to demonstrate that the carbon is in solution as such in the iron; and, in that case, it is evident that it must obey the laws of solution, and diffuse through the material until the pressure of solution is equalised throughout.

*Experiment 5 (b).*—An experiment was finally tried in order approximately to ascertain the speed of diffusion and oxidation of the carbon. Carbon dioxide is too powerful an agent for the practical oxidation of the carbon in white iron, inasmuch as the iron itself tends to become oxidised. When carbon dioxide is passed through a wrought iron tube at a red heat, the gas becomes partially reduced to monoxide until a certain definite proportion of the two gases is present in the mixture, which is no longer able to attack the metal, so that a condition of equilibrium is attained. Such a mixture cannot, therefore, oxidise the iron any further, but may be sufficiently strong to oxidise the carbon in the iron. A piece of white iron was therefore placed in an iron tube and heated to 1000° C., and was thus exposed to the action of a current of dry carbon dioxide. It was found that the carbon diffused most rapidly at the highest temperatures. The most rapid diffusion observed was in the case of an experiment in which a bar of white iron  $\frac{3}{8}$  inch in diameter lost the whole of its carbon by oxidation in twenty-two hours, and without oxidation of the iron itself.

## REMARKS ON THE EXPERIMENTS.

The majority of the slow-cooling experiments were made in a small gas-muffle. The slow cooling was brought about by

using a somewhat luminous flame, which gradually choked up the muffle with soot, so that in the end the gas could not pass up through the furnace into the chimney. For other experiments an electric furnace was fitted up. It consisted of a porcelain tube, around which was wound platinum wire. This was heated by the current from storage cells, the current being regulated by means of a dilute sulphuric resistance-cell provided with lead-sheet electrodes. The solution was gradually run out of or into the bath as required by means of a siphon.

In the diffusion experiments the analyses were made upon samples taken from the whole cross sections of the bars, and the slight discrepancy in the results is undoubtedly due in part to the impossibility of obtaining a perfectly representative sample.

#### SUMMARY OF RESULTS.

The diffusion experiments tend to show that the carbon is present in iron at a red heat in a state of simple solution. If this be accepted, an understanding of the other results becomes possible, and the interpretation to which the author has been led is as follows:—

White iron in the cold is a mixture of mass-cementite and pearly compound. The latter, again, is composed of strips of iron and cementite. When this iron is heated to the recalescence-point  $A_{R_1}$ , the cementite begins to decompose, and the iron at once dissolves the carbon of this decomposed carbide to the extent of 0·9 per cent. The pressure of this dissolved carbon is able to prevent the further dissociation of the carbide. Then, as the temperature is raised, the solvent power of the iron increases, so that it is enabled to take up more carbon. At 1030° C., the percentage of dissolved carbon is 1·5. But at this critical temperature the whole of the residual carbide is dissociated, in spite of the presence of the carbon dissolved in the surrounding iron. The iron, however, is not able, at this temperature, to dissolve more than 1·5 per cent. of carbon, so that the excess of the latter is deposited in the form of graphite as fast as it is produced by the dissociation of the carbide. If the metal be melted, the separated graphite redissolves in the now fluid iron, and on

cooling the whole of the carbon remains combined, provided that the time of cooling be not too prolonged. Even quenching the liquid solution is not able to prevent the formation of the mass cementite; but the whole of the carbon dissolved at 1030° C. is retained in combination with the whole of the iron, and forms an alloy in which the iron and carbon are in proportions corresponding approximately to the formula  $\text{Fe}_{14}\text{C}$ . The iron at 700° C. dissolves only 0·9 per cent. of carbon, and this, when quenched, forms the well-recognised alloy corresponding in composition to  $\text{Fe}_{24}\text{C}$ . There are, therefore, two opposing pressures in white iron at a red heat, one being the dissociation pressure of the carbide, the other the solution pressure of the carbon, of which the latter is normally the greater. It is evident that if the solution pressure be removed at this temperature the carbide will dissociate, or again, if the dissociation pressure be assisted in any way, so that the solution pressure be exceeded, the carbide will equally be able to decompose.

So far as the author has as yet obtained evidence, crystallisation is the only force which comes into play at this temperature. In pure iron the crystallisation-point occurs at 750° C.; in steel containing 0·2 per cent. of carbon it is observed at about 735°; while in steels with 0·8 per cent. it is lowered to about 685° (the recalescence-point  $\text{AR}_1$ ). It would thus appear that the point  $\text{AR}_2$  in low-carbon steels marks the crystallisation of pure iron alone, the iron containing carbon in solution being unable to crystallise until the dissolved carbon has passed out of solution into combination as  $\text{Fe}_3\text{C}$  at  $\text{AR}_1$ . Hence in (say) 0·2 per cent. carbon steels at 720° C., the mass should consist of pure crystallised ferrite intermixed with amorphous masses of iron containing carbon. It will be remembered that the annealed bar quenched at 720° C. along with steel in Experiment 8 (*l*) (*supra*) showed that the crystals of iron were already formed at that temperature. It would seem, therefore, that the solution pressure of carbon in iron is greater than the crystallisation pressure of the iron. In the experiments above quoted it was found that when the carbide had been in part dissociated, the whole of the surrounding solution of carbon in iron had already disappeared, and the iron had crystallised. To sum up in brief, if  $s$  be taken to represent the pressure of carbon in solution;  $d$  the pressure of dissoci-

tion ; and  $c$  that of crystallisation, then  $s$  is greater than  $d$  or  $c$ , but less than  $d+c$ . In the absence of  $c$  (that is, above 750°) slow cooling will not cause any formation of graphite. Again, in the absence of  $d$  (that is, when the iron contains no more than 0·9 per cent. of combined carbon), graphite is not produced by annealing ; nor can crystallisation occur until  $s$  has been removed at  $AR_1$ , about 685° C.

It has also been shown that, at least under the conditions of Experiment 4 (*a*), carbon is unable to combine with iron at temperatures below 620° C.

Finally, arising out of these experiments, and from those in the paper on "Malleable Cast Iron," it will be seen that below the point  $AR_1$  (since the carbon then exists in steel in combination as  $Fe_3C$ ), there can be no tendency to diffusion of carbon ; and hence no oxidation of carbon can take place without the slow penetration of oxygen into the mass.

This research has been carried out during the past two years in the Metallurgical Department of Mason College, Birmingham, during the author's tenure of the Bowen (Metallurgical) Research Scholarship. The author begs to thank Mr. W. G. M'Millan, the Lecturer on Metallurgy, for his assistance in the working out of these experiments.

He desires also to thank Professor Arnold of Sheffield for the use of his recording pyrometer ; and he is indebted to Mr. Housman, Lecturer on Electro-technics at Mason College, for kindly allowing the use of his department for the experiments involving the application of the electric furnace.

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#### [BIBLIOGRAPHY.

## BIBLIOGRAPHY.

In order to avoid confusion, no references have been given in the text. These references to a few of the principal investigations bearing on this subject under discussion are therefore grouped together as an addendum to the paper.

*Malleable Cast Iron.*—Forquignon,<sup>1</sup> in his classical research on malleable cast iron, demonstrates that the annealing is not necessarily the result of oxidation, but may be brought about by decomposition of the hard carbides.

Stead<sup>2</sup> has shown, in a research published recently, that malleable cast iron is a composite material built up of layers or rings, the composition and structure of which he describes in detail. He also discusses the annealing phenomena. The author's experiments in this direction were made independently, and prior to the publication of Stead's results.

Stanford<sup>3</sup> gives a full account of works procedure, and discusses the details of the process and the iron made.

Hadfield<sup>4</sup> gives analyses and the result of heat treatment of "black heart" iron.

Tresca and Morin, Sebastian and Brull, have also done work on this subject.

*Carbon and Iron.*—The normal carbide (cementite) has been shown by Abel<sup>5</sup> to have the composition  $\text{Fe}_3\text{C}$ , and this has been further confirmed by Osmond and Werth,<sup>6</sup> and by Arnold and Read.<sup>7</sup>

The homogeneity and want of structure of the quenched alloy of iron and carbon, when the carbon is present in the proportion of 0·90 per cent., was described by Arnold,<sup>8</sup> and afterwards by Sauveur.<sup>9</sup>

<sup>1</sup> *Annales de Chemie et de Physique*, 1881, vol. xxiii.

<sup>2</sup> *Cleveland Institution of Engineers, Proceedings* 1895 (Dec. 16), p. 79.

<sup>3</sup> *Transactions of the American Society of Civil Engineers*, vol. xxxiv. p. 1.

<sup>4</sup> *Journal of the Iron and Steel Institute*, 1894, No. I. p. 156.

<sup>5</sup> *Proceedings of the Institution of Mechanical Engineers*, 1883, p. 56; 1885, p. 30.

<sup>6</sup> *Annales des Mines*, Series 8, vol. viii. p. 5.

<sup>7</sup> *Journal of the Chemical Society*, vol. lxxv. p. 788.

<sup>8</sup> *Minutes of Proceedings of the Institution of Civil Engineers*, vol. cxxiii. p. 127.

<sup>9</sup> *Transactions of the American Institute of Mining Engineers*, February 1897.

The difference in character of carbon in quenched steel from that in normal steel, as illustrated by Eggertz' test, was shown by Hogg,<sup>10</sup> and afterwards by Ledebur.<sup>11</sup>

The phenomena of the diffusion of carbon in iron was investigated by Abel.<sup>12</sup> Curves illustrating the diffusion of carbon have been published by Roberts-Austen,<sup>13</sup> Osmond,<sup>14</sup> and Stead.<sup>15</sup>

Hillairet and Garnier<sup>16</sup> have made experiments on diffusion. An electric current was sent through two bars of iron between which was placed a pad or layer of charcoal. The carbon of the latter diffused into the cathode, but not into the anode iron.

The crystallisation point of iron has been determined by Arnold<sup>17</sup> and confirmed by Charpy.<sup>18</sup> They show that it is identical with  $\Delta R_x$ .

The formation of graphite in steel by rolling it at a dull red heat was investigated by Winder,<sup>19</sup> who found that it was necessary that the steel should contain upwards of 0·90 per cent. of carbon. Ledebur<sup>20</sup> has independently confirmed the author's discovery, recorded in this paper, that hammering has the same effect as rolling.

*Metallography.*—Sorby<sup>21</sup> is the founder of this science. He examined and described the structure of iron, steel, and cast iron. The study of the structure of iron, steel, and cast iron has been further carried on by Martens,<sup>22</sup> Osmond,<sup>23</sup> and Wedding<sup>24</sup>

<sup>10</sup> *Journal of the Iron and Steel Institute*, 1894, No. II. p. 104.

<sup>11</sup> *Ibid.*, 1898, No. II. p. 58.

<sup>12</sup> *Op. cit.*

<sup>13</sup> *Journal of the Iron and Steel Institute*, 1896, No. I. p. 139.

<sup>14</sup> *Transactions of the American Institute of Mining Engineers*, February 1897.

<sup>15</sup> *Cleveland Institution of Engineers, Proceedings* 1895, p. 54.

<sup>16</sup> Borchers and McMillan, "Electric Smelting and Refining," 1897, p. 385.

<sup>17</sup> *Journal of the Iron and Steel Institute*, 1894, No. I. p. 107.

<sup>18</sup> *Comptes Rendus de l'Académie des Sciences*, vol. cxix. p. 735.

<sup>19</sup> *Minutes of Proceedings of the Institution of Civil Engineers*, vol. cxxiii. p. 258.

<sup>20</sup> *Stahl und Eisen*, vol. xvi. p. 116.

<sup>21</sup> *Journal of the Iron and Steel Institute*, 1886, No. I. p. 140; 1887, No. I. p. 255.

<sup>22</sup> *Transactions of the American Institute of Mining Engineers*, 1894, vol. xxiii. p. 37.

<sup>23</sup> *Ibid.*, vol. xxii. p. 248.

<sup>24</sup> *Journal of the Iron and Steel Institute*, 1885, p. 187.

on the Continent, by Garrison<sup>25</sup> and Sauveur<sup>26</sup> in the United States, at home by Andrews,<sup>27</sup> Arnold,<sup>28</sup> and Stead.<sup>29</sup>

Stead has fully described his own method of preparation, along with that of the other metallographers above referred to.

<sup>25</sup> *Transactions of the American Institute of Mining Engineers*, 1886, vol. xiv. p. 913; vol. xv. p. 761.

<sup>26</sup> *Ibid.*, vol. xxii. p. 546.

<sup>27</sup> *Engineering*, vol. lxi. p. 91.

<sup>28</sup> *Minutes of Proceedings of the Institution of Civil Engineers*, vol. cxxiii.

<sup>29</sup> *Journal of the Iron and Steel Institute*, 1894, No. I. p. 292 (where a list of forty-five works on the subject is given); *Cleveland Institution of Engineers, Proceedings*.

*CORRESPONDENCE.*

Mr. R. A. HADFIELD thought their President had acted wisely in giving encouraging words of welcome to the author for his two valuable papers, which are really interdependent. He (Mr. Hadfield) was specially glad to see such excellent work coming from one who had received training at the Sheffield Technical School. Its munificent supporter, Sir F. T. Mappin, and the committee of the school would feel no little reward when they saw that its work was bringing to the front earnest and successful workers such as the author.

The paper regarding malleable cast iron was of considerable value, as it brought out details of a process upon which, at present, there was not much scientific knowledge. Although the production of malleable cast iron was essentially a process in which scientific knowledge should be of high service, the author's paper, next to that of Mr. Stead, was one of the first in which the various steps had been followed and examined in a scientific and systematic manner. To show how slight the general knowledge had been, it was not long since the average impression regarding malleable cast iron was that it was a product in which the carbon had been entirely or almost entirely removed. He (Mr. Hadfield) gave some time ago in his paper to the Institute on "The Results of Heat Treatment on Manganese Steel" \* considerable data regarding American malleable cast iron, and was glad to see that the author confirmed the results then arrived at, and had carried the investigations further so as to form a complete and valuable research.

With that and the important data of Mr. J. E. Stead in the paper just referred to, they now had information of a very complete kind respecting a process which until recently had been largely of an empirical nature. The author's paper was specially valuable, too, as calling attention to a line of work to which they in the United Kingdom had not paid sufficient attention; that was the production of malleable iron castings, for in America that industry was carried on on a very large scale. Its production

\* Vol. i. of 1894.

had been so thoroughly specialised, that he questioned whether they could touch either the price or quality which were being obtained in the United States. A large user in Sheffield had told him that he had to send for execution in America very considerable requirements, the price of the castings being exceedingly low, the quality excellent, and the time of delivery short as compared with that of English makers. The author gave information that should prove serviceable and valuable in practical application, so that he hoped the paper would arouse the attention of English manufacturers to an opening for a new business of a valuable character. The rationale of the carbon changes in malleable cast iron was so fully described by the author that it was to be hoped that those makers who had had difficulty in getting uniform results would see that they were to be readily obtained by the necessary observations of the temperature and other data so clearly shown by the author to be necessary.

There was one point which, although known before, had been well emphasised by the author, viz., the injurious nature of manganese in cast iron which had to be "malleabilised." That seemed to him to have great importance in its bearing upon the condition of carbon in its combination with iron, and strongly supported the claims of both Mr. Stead and himself, viz., as to the presence of special or double carbides of carbon and manganese. As the author had pointed out, carbide of manganese and iron could not be, or only with great difficulty, decomposed by annealing, whilst, as regarded carbide of iron alone, the carbon could be readily precipitated from its combination form into the graphitic or temper carbon of Ledebur. It was not clear what the author intended to convey by the remark on page 8, "when any graphite is left in the iron, it fails to bend double," and also as mentioned at the top of page 13, "no bend can be obtained;" possibly he was speaking of specimens in which there existed ordinary graphite as against the very finely-divided graphite or temper carbon of Ledebur, though even this should not make the great difference referred to. He thought there must be some slip in the paper, because the American malleable iron castings which he had seen, as well as those produced in England (the former, however, being the toughest), contained a very considerable quantity of graphite or temper carbon. Even in the presence

of considerable quantities of the latter, as he had shown in his paper to the Institute previously referred to, with material containing as high as 3·07 per cent. of this substance, the material could be bent in a manner almost approaching that of soft steel castings, and it had wonderfully good resisting properties to sudden blows. A very heavy tonnage of such product in the United States went into draw-bars and knuckles for car-couplers, where the strains and stresses were of the severest nature, and where brittleness should not be permitted. In replying to this discussion, he hoped the author would clear up that point.

He thought it was almost a mistake—it was certainly a misleading difference which had crept into that branch of industrial terms—to call malleable cast iron “black-heart,” or other designation, as if the product were a material of different nature. Malleable cast iron simply varied according to the different nature of the material first treated; that was, that it depended upon its chemical composition; but if that was originally the same, then the differences afterwards resulting were chiefly due to the particular percentage of carbon present, and the relative proportions of graphitic, or graphitic temper and combined carbons, or the presence of other elements such as phosphorus, silicon, manganese, and chromium. He thought that ought to be recognised so as to prevent misconception arising, that the different processes produced entirely different materials as such. As a matter of fact, he had said “malleabilising” was very similar to tempering hardened steel; according to whether the temper be much or little, the qualities or properties of the finished material varied. This had been already recognised on the Continent, where malleable iron castings were often spoken of as “tempered” castings. He had dwelt upon that point at some length, because he thought both the author’s papers held such an important bearing upon the opinions “carbonists” had regarding the reason why it was to the changes in the form of carbon that they owed the various phenomena met with in iron or steel products, whether steel or malleable cast iron, such as they were now considering.

The author gave in his paper an analysis of sample No. 25, which was very important. In that, by special annealing, absolutely all the carbon had been extracted. As he and others had always found the greatest difficulty in reducing the

carbon to as low a limit as even 0·03 per cent., he should be glad if the author would give more details upon that point. "Nil" and "trace" seemed to go too far. If the author could regularly produce such a product—and he heartily hoped that that could be accomplished—he should be glad if he could spare him a sample bar such as mentioned, upon which, he thought, experiments could be made having an important bearing upon the form of carbon existing in steel and iron alloys. He would be glad to communicate the results to the Institute. It would be important that the carbon should not exceed, either in the combined or graphitic conditions, 0·015 per cent. each at any part of the bar.

If the author had several specimens of that absolutely carbonless iron, he (Mr. Hadfield) would suggest that the cooling curve of one should be taken, as that would form an interesting addition to the paper when finally appearing in the Proceedings. In fact, it might be well to go a step further, and by means of Professor Roberts-Austen's excellent recording apparatus, to have a photograph taken of the changes occurring during the whole time a specimen was being transformed from white into malleable cast iron.

He noted that the author considered that chromium prevented the transition of carbon to the temper or combined carbon condition. It would be interesting if he would add any data upon that point, for his (Mr. Hadfield's) own experience in dealing with steel castings of equal carbon percentages, but in the one case with and in the other case without chromium, did not seem to indicate such a difference. The change might be delayed, or more of the carbon would remain obstinately combined, but still the change could certainly be effected to a greater or less degree. In this respect the action of chromium was different as compared with manganese, which very obstinately retained the carbon combination; but even in this case it had been clearly proved, in a paper read before the American Institute of Mining Engineers, that the carbon even in spiegel or ferro-manganese could be removed. After a number of experiments, made some years ago, he had found that for practical purposes that was not so. A certain change could be effected, though with difficulty.

Referring to the author's second paper, "On the Relation of

Carbon to Iron at High Temperatures," Mr. Hadfield, as a "carbonist," specially welcomed it. It embodied much excellent research work in a direction to which he had in his own papers, and in the discussion of several papers which had been read before the Institute during the last few years, urged special attention, viz., that the direction in which they would get information of most practical value, and from which they would eventually obtain a correct knowledge of the changes which occurred during the hardening of carbon steel, would be by investigating, as the author expressed it, the "relation of carbon" to iron.

If he might make a suggestion, he would ask the author to continue the excellent work, treating samples of carbon and alloy steels in exactly the same manner as he had done his white iron specimens, and reporting the results, but the highest chemical skill should accompany the research as regards the determination of the carbon results. It was quite singular how, whilst quite unknown to each other, authors widely apart in distance and race would send in papers bearing upon the same or similar questions. Hence it was that Baron H. Jüptner von Jonstorff had, at the same meeting, sent in his very important paper "On the Determination of Hardening and Carbide Carbon." With the experiments which he (Mr. Hadfield) had suggested, combined with a very exact chemical research, such as had been rendered possible by the recent labours of Stead, De Benneville, Ledebur, Arnold, and Jüptner, he believed a valuable accession of knowledge would result.

To carry on such a research, he added with pleasure, that any specimens of carbon or alloy steel he might have were at the service of the author.

Much of his contribution, as he had already stated, to the discussion of the paper on malleable cast iron, bore upon the author's second paper; but he would again emphasise what he considered to be the erroneous conclusion of the author, viz., that it was the graphite which caused the brittleness referred to. Malleable cast iron containing practically all its previous carbon in the combined condition could be very tough indeed, and any brittleness present was owing, most probably, to other elements, or to imperfect conversion of the combined carbon. That applied also to

ordinary cast iron. No. 1, or the most graphitic iron, was always considerably tougher than the same make of iron of lower grades, such as Nos. 2 and 3. By that he did not mean to say that the same iron without graphite, and of course combined carbon, would not be still stronger.

The author brought out an important fact often overlooked, viz., that high carbon steel could be made "exceedingly soft." It was a common idea that high carbon steel meant always great hardness (he was not speaking of it in the hardened condition). By proper annealing, probably resulting in the production of "cementite," as the author pointed out, this could be readily effected; hence the importance of a practical appreciation of that fact by those who used high carbon steel for various purposes where ready tooling was important, and he believed that had been specially recognised in America. There was no doubt that when manufacturers knew how to take temperatures readily and accurately, many of the difficulties met with in the treatment of steel, such as undue hardness, variation in the hardness, soft and hard places, and the like, would disappear.

As Experiment No. 3 was an important one, he hoped the author would fill in the temperature. "Bright red" did not convey an exact idea, and in all experiments when temperature was given, even if only an approximate estimate, the results were rendered much more clear.

The precipitation of graphite by vigorous hammering was, he said, certainly a very curious and interesting result. It would appear that high percentages of carbon were at a temperature of  $1030^{\circ}$  combined much less strongly; as intimately perhaps, but the union was more readily dissolved. The manner in which by raising the temperature larger proportions of carbon were taken up by the iron was also very clearly and instructively shown by Experiments 4, *a*, *b*, *c*, and *d*. In fact, the whole paper confirmed his respect for the wonderful behaviour of carbon in its combinations with iron. Why it was necessary to look in other directions for light until they had more fully solved the "carbon" problem, was a difficulty not to be readily understood. The field was so great that it was very evident that for many years to come they must go on working steadily

and without drawing rein. After reading the two papers with more than ordinary interest, he thanked the author for his contributions, and trusted that he would not cease his endeavours to assist in the accumulation of facts regarding the relation of carbon to iron.

Mr. W. G. McMillan (Mason College, Birmingham), stated that he wished to bear testimony to the painstaking way in which the author had carried through a research that had lasted over two years, and that was beset with difficulties even greater than those which had generally to be encountered in investigations of the kind. He (Mr. McMillan) had long had in contemplation a research into malleable cast iron manufacture, and was glad to have the opportunity of suggesting this field of work to the author on his appointment as the first Bowen Scholar in the College. Meanwhile, however, other investigators had been at work. Thus, to mention only two, Stead had recently published an account of his brilliant investigations, covering some of the same ground that had been explored in the present research, and Stanford had given an admirable description of actual works practice as carried on in America.

The present paper brought home with force a fact previously well known to those who had studied the matter, but very commonly misunderstood even by the authors of some elementary text-books, namely, that there are two varieties of malleable cast iron, the one introduced by Reaumur and produced by *decarburisation*, the other described at length in the valuable paper by Forquignon, and made by a process of (if he might use the expression) *transcarburisation*. Turning to the practical side of the question, it was clearly a matter for consideration by the users of malleable cast iron whether they required a material entirely free from carbon, such as Reaumur's, or one in which carbon was distributed evenly throughout the mass in the form of finely-divided graphite, as in the black-heart castings which were so favourably received in America. For many purposes, as, for example, where very thin sections were required, or where the material was to be capable of bending or twisting, the decarburised iron must be employed; but for others the black-heart material, made by transcarburisation (or converting the combined

into graphitic carbon), was suitable, and was less costly to prepare, especially in large sections. But the presence of the graphite in the most convenient form possible for reabsorption ought not to be overlooked. It was shown that black-heart castings, when heated to redness, underwent a partial recarburisation, taking up from 0·9 to 1·5 per cent. of carbon, according to the temperature to which the material was exposed. As in many of the applications of malleable cast iron, it might be necessary to braze the material, it should not be forgotten that the process was likely to leave the resulting iron harder than before, owing to the absorption of carbon; in short, the graphite-laden soft iron was converted into a graphitic steel.

But the research under discussion had a bearing upon carburising cementation as well as upon the softening of white iron. There had been two theories advanced to account for this action; one of these supposed that the carburisation was to be ascribed to the partial dissociation of carbon monoxide diffusing into the steel, and this had been warmly supported by Behrens and Van Linge so recently as 1894 (*Zeits. Anal. Chem.*, xxxiii. 513). The other assumed it to be due to the actual transference of carbon in some way from the exterior to the interior of the metal; and Roberts-Austen, in his note on the diffusion of carbon in iron (Journal of the Iron and Steel Institute, 1896, No. I. p. 139), had shown that iron might be carburised by means of carbon in the entire absence of an atmosphere of carbon monoxide. Such a transfer was at one time explained as being due to the existence of two carbides containing different proportions of carbon, of which the highest carbide was formed externally in contact with the excess of carbon, and that, by reaction with the pure iron on the inner side, formed a lower carbide. But the same ultimate result would be obtained if carbon, or a compound containing carbon, were diffused through the mass in solid solution. The existence of solid solutions is now generally accepted, and Roberts-Austen's beautiful experiments with gold-lead alloys would still be fresh in the memories of members. The author's paper afforded confirmation of the view that the cementation of steel was due to the solution and diffusion of solid carbon in solid iron up to the limit of saturation at the temperature applied. The view that iron carbide was formed, and that

this diffused as such in solution in the iron, appeared to be negatived by the quantitative experiment described in the paper on the "Relation of Carbon to Iron at High Temperatures," where it was shown that the alteration in the percentages of carbon in the two samples of iron, which were heated in contact with one another, corresponded exactly to the total alteration in the weights of the specimens.

Mr. F. OSMOND thought that Mr. Royston's paper "On Malleable Cast Iron" did not add much information to that given in the papers already published by Forquignon and by Mr. Stead.

The second paper, "The Relation of Carbon to Iron at High Temperatures," called for some observations.

The old term "combined carbon" caused confusion, since a part only of this carbon was actually "combined." In a research on the mode of existence of carbon, it would have been better, it seemed to him, to adopt the nomenclature of Professor Ledebur, and to try to estimate separately the carbon of the carbide and the hardening carbon.

The author considered, as did Professor Arnold, that the point Ar2 is the crystallisation point of iron. It would be interesting to know what is the state of iron above Ar2.

It was found by Mr. Royston that a metal containing 1·50 per cent. of carbon, quenched at 1030° C., presented no structure, even under an enlargement of 860 diameters. According to Professor Arnold, such a metal ought to contain 11 per cent. of cementite and 89 per cent. of "sub-carbide," which appeared to be practically accurate if the quenching was not extremely rapid. If the quenching was extremely rapid, one ought, Mr. Osmond considered, to find a mixture of saturated martensite (the "hardenite" of Howe, and the sub-carbide of Arnold) and of austenite.

The result of these experiments appeared to be that the graphite in white pig iron and in extra hard steels was formed at a temperature of about 700° to 750° C., on account of very slow cooling, whatever might be the length of the operation of annealing and the maximum temperature attained, provided that this temperature had not exceeded the point of solidification of white cast iron. This was an interesting indication which deserved to be noted.

Finally, the author concluded from his experiments that carbon was dissolved in iron at a red heat; he said, in his own words, "When the iron is heated to the recalescence point, Ar<sub>1</sub>, the cementite begins to decompose, and the iron at once dissolves the carbon of the decomposed carbide to the extent of 0·9 per cent. The pressure of this dissolved carbon is able to prevent the further dissociation of the carbide. Then, as the temperature is raised, the solvent power of the iron increases, so that it is enabled to take up more carbon, &c. . ." These conclusions were directly opposed to those of Professor Arnold, and Mr. Osmond approved of them the more readily because they had been borrowed \* almost literally from one of his own papers.

Mr. E. H. SANITER said that whilst in no way wishing to derogate from the credit due to the author for his investigation, or the ability with which he had carried it out, it seemed desirable to point out the remarkable similarity between the author's paper and that by Mr. Stead on the same subject, read before the Cleveland Engineers in 1895. That similarity suggested to him the question, Why publish in such detail results which might have been summarised in a sentence as confirming Mr. Stead's work? He was inclined to think that the scanty reference in the bibliography of the author's other paper was hardly sufficient acknowledgment of Mr. Stead's pioneer work in this direction. It might also be pointed out that the author's view that carbon was in simple solution in iron ("Relations of Carbon and Iron at High Temperatures") had been held by Osmond and others for a very long time, but was now being relinquished by them in favour of the idea that the carbon was in solution in the iron in the form of a carbide of iron.

Mr. J. E. STEAD, Member of Council, said it would appear that both the author and himself had been engaged in a similar investigation for some time past, and that the results were obtained independently. The preliminary report on his (Mr. Stead's) work on malleable castings was published in the Proceedings of the Cleveland Institution of Engineers, December 1895, and it was satisfactory to note that the results published

\* *Minutes of Proceedings of the Institution of Civil Engineers*, vol. cxxiii. p. 245.

to-day, practically speaking, coincided with his own. In justice to him, he must point out that the author had supplemented his (Mr. Stead's) work by complete analyses of the various parts from the malleable castings, and had shown that, excepting the carbon, practically no change was effected in the sulphur, phosphorus, and manganese. He had also given valuable mechanical tests.

He (Mr. Stead) was, he thought, the first to point out that silicon itself in solid pig iron could be oxidised to silica at the surface without the iron being oxidised to any material extent, and that the silica so formed enveloped the grains of iron which remained in the metallic state. The metallic scale from the surface could be readily obtained intact by bending thin specimens of malleable castings, and if such scale was dissolved or treated with acid, the whole of the iron was removed, leaving a beautiful cellular network of meshes of silica visible under the microscope. He was still continuing the research on malleable castings, but thought it would be premature to give results at present.

Mr. ROYSTON, in reply, stated that he had read with much interest the correspondence on his two papers, and wished to thank the gentlemen who had contributed to the discussion.

The conclusion was questioned by Mr. Hadfield in his very courteous criticism, that when any graphite remained in the iron, the bars failed to bend double. That, however, was certainly the author's experience. The best bending tests he had obtained were bends of an angle of  $90^{\circ}$  with bars  $\frac{3}{8}$  inch thick. The same size bars, which had been decarbonised, gave a double bend without sign of fracture, and equal in quality to wrought iron bars. At the same time, there was no appreciable difference in the hardness, or in the quantity of combined carbon dissimilar in toughness and ductility, apart from the bending tests.

The author, when making his analyses of these materials, had not in view the production of absolutely carbon-free iron, still he anticipated no difficulty in the making such, if the iron were perfectly free from carbon-retaining elements, such as manganese, &c. The author's experiments on the effect of chromium on carbon transition were made with carbon alloys of 3·5 per cent.

Under conditions which, in the carbon-iron alloy produced a graphitic result, the introduction of 3 per cent. of chromium gave an iron which contained only combined carbon. The author noted that Mr. Osmond thought the "Malleable Cast Iron" paper contained only information that had been previously published, and in which opinion Mr. Stead and Mr. Saniter concurred. The paper, however, contained the reactions of the annealing processes, now published for the first time. The publication of these might be the means of preventing chemists from examining the lime in which castings had been annealed, and feeling disappointed at the absence of calcium carbides or a sub-oxide of calcium.

Mr. Stead claimed to be the first to show that silicon in pig iron might be oxidised without the iron being oxidised to any material extent. The author agreed with Mr. Stead, and his results showed that the oxidation did take place. The author, however, always found this difference, that the iron itself contained several units per cent. of combined oxygen.

As to the other paper, the author would have been much interested to hear Mr. Hadfield's opinion as a "Carbonist" on the rationale of the "relation of carbon to iron" above Arl found therein, and which had been received by his opponents, the "Allotropists," with approval. The temperature which Mr. Hadfield pointed out as omitted was about 850° C.

Mr. Osmond's remarks were of great interest, and it was with pleasure the author read of his approval of his conclusions.

So many theories had been advanced to explain the changes taking place at a red heat in carbon and iron alloys, that it would have been remarkable had none of these hypotheses contained at least some part of the actual truth.

As Mr. Saniter pointed out, Mr. Osmond brought forth the theory of simple solution some years ago, but some time ago withdrew it and adopted another—namely, the carbide solution idea, which, as Mr. McMillan pointed out, was negatived by Experiment No. 5. It was evident, therefore, that Mr. Osmond was not quite happy in his expression when he accounted these views of the author's as being *borrowed* from him. The author would also disagree with Mr. Osmond as to his rendering of Professor Arnold's account of 1·5 per cent. carbon steels when

quenched at 1030° C. Were not Professor Arnold's bars quenched at a lower temperature?

In conclusion, the author would confess his inability to obtain Mr. Osmond's soft carbide austenite. This he regretted, as the formation of this substance in place of the normal carbide would remove the necessity of long annealing white iron in the manufacture of malleable cast iron.

On the motion of the PRESIDENT, a vote of thanks was accorded to Mr. Royston for his papers.

The papers by the Baron von Jüptner, by Professor Hartley, by Mr. F. J. R. Carulla, and by Mr. T. D. West were then taken as read.

The PRESIDENT moved the usual vote of thanks to the President, Council, and Secretary of the Institution of Civil Engineers for the use of their rooms; and this having been formally seconded by Sir LOWTHIAN BELL, Bart., Past-President, it was carried unanimously.

Mr. THOMAS WRIGHTSON then proposed: "That the cordial thanks of the Iron and Steel Institute be, and are hereby tendered to the President for his admirable conduct in the chair."

Mr. JEREMIAH HEAD seconded the motion, which was carried enthusiastically.

The PRESIDENT, in acknowledging the compliment, announced that the next meeting of the Institute would take place at Cardiff in the first week in August.

REPLY OF HENRY M. HOWE TO THE DISCUSSION OF HIS  
PAPER ON "THE HARDENING OF STEEL."

(*Journal*, 1895, II. p. 258.)\*

THE evidence in my paper on two important points, each tending to show that some primary cause other than carbon operates in the hardening of steel, has been criticised. The first of these, that nearly carbonless iron is strengthened by rapid cooling to a degree out of proportion to its carbon-content, is criticised by Mr. Hadfield. The second, that in the slow cooling of low-carbon steel, part of the hardening power is lost before the condition of the carbon changes, has been criticised by Professor Arnold, who also charges me with certain errors. Professor Arnold also represents that a theory which I offered is opposed to chemical laws.

To these three points my reply is chiefly confined.

*Sudden cooling strengthens nearly carbonless iron.*—Mr. Hadfield objects to my evidence (*Journal*, 1895, II. p. 275)—

1. That it is based on thin specimens.
2. That stress, and the carbon- and manganese-content, suffice to explain the strengthening, without invoking allotropy.
3. That the specimens may have absorbed carbon while heating, prior to the sudden cooling.

1. *Thin Specimens.*—If we seek to preserve allotropic iron by sudden cooling, our conditions must be fitted for its preservation. Evidence that it is not retained under conditions unfavourable to its retention proves nothing. It is admitted by all that, if allotropic iron can be preserved at all in the absence of carbon, manganese, &c., it can be only with great difficulty, and hence only by a most rapid cooling; and this obviously is possible only with very thin pieces. Even with thin pieces, the needed rapidity is not easily attained. It is easy to fail in a difficult experiment. Moreover, in thin specimens, the influence of stress should be less than in thick ones, because stress is due to inequality in the rate at which different layers cool, and this inequality may be measured at any given instant by the thermal

\* A critical illness has prevented me from preparing this reply in time to appear in the volume which contains the discussion (*Journal*, 1896, I. p. 170), or even in the succeeding volume.

gradient as we pass from without inwards. Clearly this gradient is steeper in thick than in thin pieces. Hence, compared with thick pieces, thin ones have a double advantage. In them allotropic iron should be more completely preserved, and hence more readily recognised by its greater strength: the stress is less, and we have thus the less reason for referring their strengthening to stress.

2. It hardly seems necessary to discuss the question whether the carbon- and manganese-content of the nearly carbonless steels which I quoted, suffice to explain satisfactorily, by the direct action of these two elements, the great strengthening which sudden cooling here causes; for the results which I now give in Table VI. go to show that very important strengthening occurs in the sudden cooling of pieces so thin, that stress should not be great, and so free from carbon and manganese (containing only 0·022 per cent. of carbon, and no manganese), that these elements afford no reasonable explanation of the strengthening.

TABLE VI.—*The Hardening of nearly Carbonless Iron.*

Bar No.	Size in Inches.	Size of Transverse Holes. Inches.	Tensile, Pounds per Square Inch.	Elastic Limit, Pounds per Square Inch.	Elongation, per Cent. in One Inch.	Contraction of Area per Cent.	Treatment.
29·6	·162×·174	...	48,580	23,050	44	72·3	Cooled very slowly from 930° C. Not bored out.
29·10	·187×·204	·082 and ·083	49,890	...	...	...	Ditto, and bored out after slow cooling.
29·2	·176×·181	...	52,040	30,400	43	77·8	Quenched in water at 17° C. (63° F.) from 930° C. Not bored out.
29·9	·183×·198	...	67,400	42,820	28	58·56	Quenched in iced brine at -7° C., from 930° C. Not bored out.
29·3	·177×·186	·073 and ·073	70,690	...	...	...	Quenched in iced brine from about 930° C., and then bored out.
29·7	·178×·197	·084 and ·084	60,190	...	...	...	
29·8	·179×·195	·087 and ·087	62,450	...	...	...	
29·12	0·1717 diameter	...	72,400	...	18	75·9	Quenched in iced brine at -8° C., from about 930° C., then turned down to 0·112 inches diameter, and then tested tensilely.

NOTE TO TABLE VI.—This steel was kindly supplied to me by Mr. H. H. Campbell, Superintendent of the Pennsylvania Steel Company, and was made under the direction of that distinguished metallurgist in the basic open-hearth furnace. It contained—

Carbon. 0·022	Silicon. trace.	Manganese. 0·00	Phosphorus. ·007	Sulphur. ·014	Copper. ·10
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The carbon and manganese were determined by Booth, Garrett, and Blair, the former by com-

bustion, in a sample after I had treated and tested it, so that there is no question about its having taken up carbon after analysis and before testing.

The bars were machined out of a block of this steel, were heated approximately to 930° C. in the double-walled muffle described in my paper. The bars which were quenched were drawn from the furnace for this purpose immediately on reaching 930°. The slowly-cooled bars were left in the furnace and allowed to cool down very slowly.

In order to show whether the strengthening effects were in large degree due to stress, each of the bars 10, 3, 7, and 8, had two intersecting holes drilled across it, in the middle of its length, of the dimensions shown in Table VI., thus reducing the remaining section to four rectangles at the four corners. This was done after the bars had been quenched.

One of the slowly-cooled bars was bored out in the same way, to show whether this peculiar form of section could materially affect the properties of the specimen.

In drilling these holes, the bars were sprayed copiously with rhigolene, so that their temper might not be drawn by the heat due to the machining.

The specimens were all tested tensilely by the Eichle Brothers Testing Machine Company.

The strength of a quenched wire of the same steel was reported to me as 114,000 pounds per square inch; but, on repeating the experiment several times, I have failed to get such great strength. On inquiry, I believe that the testers must have erred in calculating this result.

To test the truth of Mr. Hadfield's belief that this strengthening and embrittling are either superficial or due to stress, I bored out the interior of three bars after quenching them (3, 7, and 8), and I turned off the outer part of one bar (12), also after quenching. Each of these procedures subsequent to quenching should lessen stress, and the last should completely remove superficial action. Strange to say, boring out the interior of the bars after quenching actually exaggerated the effects of quenching; and, stranger still, removing the exterior of bar 12 still further exaggerated the effects, although the average rate of cooling for this residual central core was of course much less rapid than for the bar tested whole.

I shall try to verify these remarkable and indeed unexpected results. They agree surprisingly with those which I obtained with a steel bar containing 0.39 per cent. of carbon which I treated in like manner. In this case the tenacity of the central core of the hardened bar was 248,000 lbs. per square inch, against 166,000 lbs. for the outer shell of the same bar, and 118,000 lbs. for the bar tested whole after the same hardening.\*

Whether I am right or wrong in my surmise that this greater tenacity of the relatively-slowly cooled central core of these bars is due to the retention of allotropic iron by the enormous pressure, these results I think suffice to show that the strengthening and embrittling of this practically carbonless iron is not superficial. They also go to show that it is not solely due to stress, though this latter point is more powerfully shown by the fact that metals other than iron are not comparably strengthened by

\* The Metallurgy of Steel, p. 33, 1890.

sudden cooling (so far as we now know), although they ought to receive stress quite as it does.

The strengthening of this nearly carbonless iron by sudden cooling thus seems to be due to some cause other than the direct action of carbon, other than manganese, and other than stress. In view of the strong evidence that iron becomes allotropic in the critical range, allotropy seems to me far more likely than anything else yet suggested to be that other cause.

3. The fear that my steels may during heating have absorbed carbon, which might give them hardening power, is groundless. My specimens were heated within a double-walled copper muffle, which was heated in a gas flame: the inside of the muffle was abundantly coated with cupric oxide; the conditions were so far from being carburising that the steel always became coated with oxide, and I had to take pains to prevent the formation of a thick scale, which would, of course, retard the cooling. Indeed, the carbon of Series 29 (Table VI.) was determined in a bar after it had been treated and tested.

To Mr. Hadfield's evidence in rebuttal I reply:—

1. That the relative slowness of his coolings, due both to the excessive thickness of his specimens and to the relative inefficiency of his cooling medium, would suffice to explain why he should fail where I have succeeded in the strengthening this nearly carbonless metal.

2. That evidence obtained with so heterogeneous a substance as wrought iron should be based on a far greater number of tests than he gives us.

3. That, despite his unfavourable conditions, and even with his extremely low carbon- and manganese-content, his cooling actually was rapid enough to affect his metal very greatly, in one case raising its yield-point by 81 per cent., quite as good evidence of the preservation of allotropic iron as increase of tenacity is.\*

\* The evidence which Mr. Hadfield offers to show that carbonless iron cannot be affected by sudden cooling seems to me weak. His failure to strengthen some of his bars, in view of the fact that he has strengthened another, and that I have strengthened mine, may be explained by supposing that in certain cases he has not observed the necessary conditions. Since these very low carbon irons can be strengthened apparently only by the most rapid cooling, it is reasonable that the strengthening should be defeated by any slightly retarding circumstance, such as the presence of a thick coating

4. The hardening of nearly chemically pure iron is, however, so important a matter that we cannot accept it confidently until evidence fuller than mine is given. We need especially to confirm the surprising results which I have given, and to show that similar results cannot be induced in the other metals by sudden cooling.

5. While evidence that nearly pure iron can by sudden cooling be strengthened to a degree too great to be readily explained by the quantity of foreign elements present would powerfully support the allotropic theory, yet evidence that it could not be so strengthened would not in itself oppose that theory, except in so far as it would remove a piece of evidence in its support. Indeed, the very fact that different elements are found independently capable of conferring the hardening power argues rather for than against that theory, as I explain later on.

of scale on the bar, failure to move the bar rapidly in the water, &c. At any rate, a single instance of unquestioned strengthening of this practically carbonless iron is, as evidence bearing on this question, worth twenty cases of failure to strengthen. The twenty and one cases taken jointly would simply show that it is possible, though difficult, to harden such iron. But even this would give two valuable indications: first, that allotropic iron exists, thus supporting the other indications to that effect; next that, even in the almost complete absence of carbon and other favouring elements, some of it can be retained by sufficient skill, which makes it easier to believe that much of it is retained when these favouring elements are present. Now this is all that the allotropic theory here asks.

But the case is actually far stronger: as I have just said, Mr. Hadfield himself has greatly strengthened one of his bars by sudden cooling. This is bar 1979. Comparing it with the slowly-cooled and apparently like bars 1978 F and 1980 F (we cannot compare it with 1976 F, because the thermal treatment of this is unknown), we find that the sudden cooling has not only increased the tenacity by 36 per cent. (not as Mr. Hadfield by a slip reports it, "but a little over 25 per cent."), and lowered the elongation by 36 per cent., but has actually raised the yield-point by 81 per cent. Considering the large section of his piece, and his relatively slow method of cooling, this is all that could be expected. Mr. Hadfield has apparently overlooked this elevation of the yield-point, which is quite as good evidence of the preservation of allotropic iron as an increase of tenacity is; and of course the enormous elevation of the yield-point which he records cannot be referred to malobservation, especially as his mechanical tests seem to have been made with care.

By quenching a wrought iron bar I reduced its elongation from 25 per cent. to 6 per cent. and 3 per cent., although I slightly lessened its tenacity ("The Metallurgy of Steel," 1890, p. 32).

Styffe found that charcoal-hearth iron, containing only 0·07 and 0·08 per cent. of carbon, had its tenacity increased by 41 and 40 per cent. respectively, and its elongation decreased by 79 and 47 per cent. respectively, by quenching in water from redness (*Iron and Steel*, Sandberg's translation, p. 137). A commission for testing old boiler material found that wrought iron containing carbon 0·06 per cent., silicon 0·06, manganese 0·27, phosphorus 0·20, sulphur 0·007, and copper 0·172, had its tenacity

To sum up: my evidence, while not yet full enough, is supported, not only by my later tests, but to a certain extent even by the very evidence which Mr. Hadfield offers in rebuttal. His objections to my conditions break down on examination. His belief that the strengthening is due to stress seems untenable.

*Professor Arnold's Results.*—As a step preliminary to examining these, let us see how matters stood before I experimented with my steel of 0·21 per cent. of carbon.

It was intrinsically difficult to show whether allotropy played any part in hardening, because we had no direct means of detecting the supposed allotropic iron, even qualitatively. Hence our procedure had to be something like what the search for Neptune would have been, if that planet, in addition to being unrecognised, had been invisible. We could then verify its existence only through the perturbations which it caused in the motions of other planets. So here we could show that allotropy played a part

considerably increased, and its elongation greatly lessened by quenching in water (*Zeit. Vereins Deutsch. Ingenieure*, xxxviii., Nov. 3, 1894, p. 1305).

While these results are far less convincing than mine with 0·22 per cent. carbon steel, they tend in a general way to show that almost carbonless iron is materially strengthened and embrittled, even by moderately sudden cooling.

I attach, however, relatively little weight to Mr. Hadfield's and these other results with wrought iron, because it is so heterogeneous. The tenacity, elastic limit, and in a measure the elongation and reduction of area of a test-piece, are those of its weakest and most ductile spot. Hence a recorded difference between two test-pieces may be due, not to their recorded differences in thermal or mechanical treatment, but to an unrecorded difference in the initial weakness of the weakest spot in the two test-pieces respectively, and in the case of so very heterogeneous a substance as wrought iron, this latter difference may easily be great. This consideration applies to the relatively uniform ingot metal, whether soft or hard steel, with much less force, though even in case of steel our tests should be numerous, if an important point is to be established.

In considering these results and those in Table VI., the important point is that the tenacity, or elastic limit as the case may be, of the suddenly cooled metal, is very far above that which, for the composition, is normal for the slowly cooled state. And, in judging whether strengthening has occurred here, this is the safer basis for comparison. The strength of the slowly cooled bar of the same steel is given, rather as showing that there is nothing abnormal about the nature of the metal in its slowly cooled state, than as the most trustworthy basis for measuring the strengthening effect of the sudden cooling.

Be it further remembered that, in judging whether allotropy or isomerism occurs, it is sufficient to know surely that a difference in any one property, inexplicable on purely mechanical grounds exists. Allotropic varieties might resemble each other in every respect save one—a difference, clearly established in any one property, and inexplicable on mechanical and physical grounds—would prove allotropy, though, of course, very strong proof of such a single difference would be needed. It is in view of this that, in discussing later on Professor Arnold's results, I confine myself to his tensile tests.

only by indirect methods, such as proving first that perturbations, or rather discrepancies, existed between the degree of hardening in any given case on one hand, and the quantity of hardening carbon and other supposable causes on the other hand ; and, second, that the discrepancy either is most readily explained by allotropy, or cannot be explained readily by any cause except allotropy.

Thus, our course was to examine the cases where there was reason to suspect a discrepancy between the degree of hardening and the quantity of hardening carbon ; and, if a discrepancy were found, to see whether it was to be referred to allotropy.\* At first, qualitative indications were to be sought.

The strengthening of the nearly carbonless iron, which I have already considered, was the first case of such discrepancy. Our evidence tended to establish this discrepancy, and showed that it could not readily be referred to stress, and that allotropy remained as the only reasonable cause.

A second important case of discrepancy had been reported by Mr. Osmond, who found that in the slow cooling of low-carbon steel, *i.e.*, of those steels which undergo the upper retardations as well as Arl, the hardening power was lost at the upper retardations, but that the carbon did not change its condition till Arl was reached, indicating that the hardening power was wholly divorced here from the change in carbon condition. This, if true, would go far to establish that feature of his allotropic theory which holds that carbon confers the hardening power, not directly

\* This, the essential feature of the situation, seems to have escaped many writers. Thus we find a most surprising assertion in Mr. Hadfield's remarks, that "to sum up briefly respecting" the remarks of Messrs. Sauveur, Osmond, and myself, we do not meet the facts given by Professor Arnold and himself in certain papers. So far as I understand, there is nothing in any of those papers to meet. Evidence like theirs, tending to show that, under certain conditions, hardening can be explained by the condition of carbon, is here beside the mark. Such evidence is wholly equivocal, for it can be explained either by the allotropic or the carbon theory. Mr. Hadfield must see that, to imagine a case, it is useless to show that Neptune does not disturb Uranus when they are farthest apart, and when the conditions do not permit perturbation. It is useless to show that we cannot detect allotropy under conditions which necessarily prevent its detection : we must seek it, not where it cannot, but where it can be found, *i.e.*, under the conditions where we have reason to believe that, if it exist at all, its influence can be detected. If carbon mask it under ten thousand conditions, and yet if we can reveal it clearly and unquestionably under one, that one is to the others as one trustworthy witness who, being present and watching, has seen, is to ten thousand who, absent or sleeping, have not seen.

by forming some special combination with the iron as the carbonists have it, but indirectly by restraining some change which tends to occur at the upper retardations, and is not a change in the condition of carbon; in short, that the presence of carbon is not a primary cause, but only a favouring or permissive condition of hardening.

Next, the wholly distinct facts (1) that these upper retardations are accompanied by the recovery of the magnetic properties, in itself a strong indication of an allotropic change, and (2) that they occur (Roberts-Austen) in wholly carbonless iron, argue strongly that these retardations represent an allotropic change. Hence Mr. Osmond's report that they coincide with the loss of the hardening power, if accepted, argues powerfully that this hardening power is the result of allotropy. Here, then, was a second discrepancy, which, like the first, pointed to allotropy as its cause.

For a long time this report of his seemed almost the only strong evidence for the allotropic theory. If true, it would support the allotropic theory very powerfully, because, while foretold by that theory, and thus in perfect accord with it, it would exclude the only other cause which has appeared competent to explain hardening, to wit, the condition of carbon.

Stress seemed to exclude itself as a primary cause, because it would fail completely to explain the phenomena in hand, viz., the loss of the hardening power at the upper retardations; for we can see no reason why stress, if the primary cause, should, on simply lowering the quenching temperature from above the upper retardations to below them, abruptly cease to induce hardening.

My early crude experiments contradicted Mr. Osmond's report, and indicated that, in the slow cooling of these very steels, the loss of the hardening power did not thus precede the change in the condition of carbon. This, if true, would remove one of the main supports of the allotropic theory.

Our knowledge being in this condition, it was to this particular discrepancy, to verify or disprove it, that my experiments with my steel of 0.21 per cent. of carbon were addressed. Their specific object was to learn whether, as Mr. Osmond had reported, part, or even the whole, of that hardening power was lost

at the upper retardations without corresponding change in carbon condition ; or whether, as the carbonists believed, the loss of the hardening power occurred *pari passu* with the change in carbon condition. In other words, what discrepancy, if any, there was between the progress of the change in the condition of carbon and the progress of the loss of the hardening power.\*

\* I supposed that I made this sufficiently clear in my paper by the following enunciation :—"The object of the investigation was to learn how closely the change in the condition of carbon, in passing through the critical range, coincides with the loss of the hardening power" (*Journal*, 1895, No. II., p. 303). Yet I do not seem to have been understood, for neither in Professor Arnold's nearest approaches to an enunciation of my aim—"Mr. Howe's specific object was to ascertain the exact influence of carbon on the hardening of iron," and "Mr. Howe had taken a steel containing 0·21 per cent. of carbon to ascertain its tenacity when suddenly quenched from various temperatures"—nor elsewhere in his remarks do I find either any reference to that discrepancy, that loss of the hardening power at the upper retardations without corresponding change in the carbon condition, which was the object of my search. Just what he regards as my aim I cannot make out confidently ; but I infer from divers remarks that he supposes my inquiry to be "How much hardening power 0·21 per cent. of carbon, *in the absence of other elements*, confers on iron at different temperatures." His assertion that my "specific object was to ascertain the exact influence of carbon on the hardening of iron" could hardly be farther from the truth. We had reason to suspect that some cause in addition to carbon played an important *rôle* in hardening, and my specific object was to learn what *rôle*, if any, this other cause played. It is much more nearly exact to say—"Mr. Howe's specific object was to ascertain the exact influence of the causes *other than carbon* on the hardening of iron," which is almost the opposite of what Professor Arnold says. The presence of manganese, though it would clearly prevent us from learning the exact influence of carbon, may aid us greatly in studying the influence of causes other than carbon.

Thus, though my aim was strictly pertinent to the general inquiry of my paper, and though my steel was well fitted for this aim, what Professor Arnold seems to regard as my aim manifestly could not be that aim, because my steel is clearly completely unfitted for it, and because it has but little, if any, bearing on the general inquiry of my paper. It is unfortunate that we have been thus at cross purposes.

Let us now consider his presentation of my reasoning. He says :—"From the relations existing between the tenacities and quenching temperatures, Mr. Howe had deduced a new and startling theory." How near is this to the truth ?

In showing that part of the hardening power, part of the power of being strengthened by sudden cooling, actually is lost at the upper retardations without corresponding loss of hardening carbon, I showed that, besides hardening carbon there is another, a second, primary cause of hardening, which is connected with these upper retardations. This fact favours the allotropic theory, because the occurrence of these upper retardations in carbonless iron, and the recovery of the magnetic properties in them, identifies them with allotropy, and because the strengthening of nearly carbonless iron by sudden cooling indicates that allotropic iron is stronger than normal iron. But though my results thus favour the allotropic theory, I do not see that they favour the carbo-allotropic as distinguished from the allotropic theory, for the former looks beyond allotropy to an allotropic carbide as this second cause ; and I see nothing in my results here in question to suggest such a carbide rather than allotropic iron as this second cause. The carbo-allotropic theory, which is the novel one here called "startling" by Professor Arnold, was in fact suggested and supported by the wholly distinct considera-

My results showed very clearly that the truth lay between these two opposing beliefs; that a large part of the hardening power was lost at the upper retardations and without corresponding

tion that when, as in manganese, nickel, and quenched low-carbon steel, we seem to get allotropic iron, we do not get the most distinctive of all the characteristics of hardening—intense mineralogical hardness and brittleness. Yet he repeatedly asserts that this theory is founded on these 0·21 per cent. carbon results, thus completely missing my reasoning.

Further, each of his three assertions (*a*, *b*, and *c* below) to this effect, besides being thus incorrect, is also surprisingly incorrect in other respects.

(*a*) "From the relations existing between the tenacities and quenching temperatures, Mr. Howe had deduced a new and startling theory." Here are two, if not three, errors: (1) That theory is not based on these data; (2) the support to the allotropic theory from these data is based, not on the relation between the *tenacity* and the *quenching temperature*, but on the discrepancy or relation between the *hardening carbon* on the one hand, and the *tenacity*, *ductility*, and *hardness* jointly on the other hand. To these I should add (3), the theory is not startling in my opinion.

(*b*) "Mr. Howe, in proposing a new theory . . . had founded his deductions upon an initial mechanical error of 65 tons per square inch." Here are at least two complete and serious errors. (1) As before, this theory is not founded upon these results; (2) there is no error, mechanical or other, of 65 tons or other amount; (3) to say even that the support actually drawn for the allotropic, as distinguished from the carbo-allotrophic theory, is based on this true datum (wrongly alleged to contain a 65-ton error), would be most misleading, for that support is drawn, not from any one datum, but from the loss of the hardening power at  $A_{13}$  without corresponding loss of hardening carbon, i.e., on a comparison of several sets of data. His expression is so loose as to mislead.

(*c*) "Mr. Howe actually selected a material containing eight times more impurity than carbon, including no less than 1·2 per cent. of manganese and 0·3 per cent. of silicon. Mr. Howe having . . . obtained a set of results of this material, he founded upon them an elaborate theory . . . on the basis that his iron contained only carbon, or that the manganese and silicon present would not influence the tenacities of the quenched bars." Here are two important errors: (1) This theory is not founded on these results; (2) I draw no inference whatever from these results on either of the bases which he here gives. The reasoning was that, as the upper retardations were identified with allotropy, a loss of the hardening power there, if not due to carbon, was probably due to allotropy. The presence of manganese and silicon might well influence the degree of hardening, but as a favouring or permissive condition, not as a primary cause.

Another and very surprising misunderstanding of my reasoning is that "the conclusions arrived at were based upon experimental data occupying only a single page," while, in fact, they are based on a general review of all the evidence treated in the whole 45-page paper. Indeed, while I had succeeded in presenting on "a single page" a condensed statement of certain of my results, this statement really represented many hundred determinations and much laborious experimenting, the discussion of which occupies six pages. I had not supposed that it was a reproach to be able so to condense one's results as to present them synoptically on a single page. His words hardly convey a correct idea of the facts.

Prominent among the facts reviewed by me which he here loses sight of are these:—

1. The retardations of carbonless iron.
2. The great hardening of very low-carbon steel.
3. The relation between the properties of manganese-, nickel-, and hardened low-carbon steel, and those of hardened high-carbon steel.

change in carbon-condition, but that another and large part occurred at and near Ar<sub>1</sub>, with roughly proportional change in carbon-condition. I established, for this steel at least, two previously disputed facts : (1) That the upper retardations, even in the presence of carbon, do not represent a change from hardening to cement carbon ; \* and (2) that nevertheless they do represent a loss of hardening-power. The first of these facts further strengthened the already strong indications that the upper retardations represent an allotropic change : the second showed that whatever change they represent here involves the loss of part of the hardening power.

The results presented by Mr. Sauveur and myself † showed that the upper retardations were here accompanied by a change of some 64 per cent. of the steel from the condition of martensite to that of ferrite ; but I do not see that they threw much light on the further question whether allotropy was or was not the underlying cause of that change. They further showed that Ar<sub>1</sub> represented a change of the remaining martensite to pearlyte ; and they thus tended to confirm my previous evidence, that the upper retardations were not connected with the change in carbon-condition, by showing that a definite structural change, the generation of pearlyte, which suffices to represent this change in carbon-condition, does not accompany the upper retardations, but occurs at and near Ar<sub>1</sub>, roughly in proportion to the change in carbon-condition which I had reported.

The very important results which Professor Arnold contributes in his Table I., obtained with steel like mine of 0·21 per cent. of carbon, except that it lacks the large amount of manganese and silicon which mine contained, indicate that the total amount of the hardening power, and the total amount of the loss of that power which occurs not only at the upper retardations but also at Ar<sub>1</sub>, increased with the quantity of manganese, or of silicon, or of both. His inference from this and the attendant facts seems to be that the loss of the hardening power at the upper retardations is due, not to an allotropic change, but to the splitting up of some double carbide of iron and manganese. While this

\* At least as far as the Eggertz colorimetric test is competent to prove this. It is very desirable that these results should be confirmed by Abel's or some other independent method.

† *Journal*, 1896, I. p. 170.

explanation, on its face reasonable enough, may be the true one, not only does the assumption that it must be the true one appear to me quite unjustifiable, but some important considerations seem to me to oppose it very strongly, and to point to allotropy as the cause of this loss of the hardening power. These considerations are as follows:—Even Professor Arnold's steel, nearly free from manganese and silicon, loses at Ar<sub>2</sub> a very large proportion of its hardening power, no less than 30 per cent. of the whole, or by his own showing as much as it loses at Ar<sub>1</sub>. Now, were this loss an isolated fact, we should not refer it to allotropy. But, occurring as it does at a retardation identified with allotropy by independent considerations, and corresponding as it does to the loss of the hardening power, great both in absolute amount and in percentage of the total hardening power which my steel undergoes at the upper retardations, it certainly does not oppose the allotropic theory, but seems to me rather to support it, as I will now try to explain.

Our two steels, taken jointly, point to two laws:—

I. A large proportion of the hardening power is lost at the upper retardations, be manganese present or absent.

II. This loss increases both in absolute amount and in the proportion which it bears to the whole of the hardening power, as the quantity of manganese and silicon present increases.

Of course further evidence is needed to establish these laws firmly. Taking them as they now stand, however, they seem to agree much better with the explanation that this loss is due to an allotropic change than with Professor Arnold's idea that it is due primarily to the decomposition of a double carbide of iron and manganese. Let us now consider the bearing of each of these laws.

The second law of course agrees easily with his idea, but no less easily with the allotropic theory, which regards the presence of manganese not as a primary cause of hardening, but as a permissive condition, like rapidity of cooling and pressure. It holds that manganese plays a catalytic brake-like rôle, like that of carbon, so far retarding the change from allotropic to α-iron that a sudden cooling is able to retain part of the iron in the allotropic state, retaining the more allotropic iron the more manganese is present. This explains satisfactorily why the hardening power

increases with the percentage of manganese. In support of this view, the allotropists can point to the fact that a large enough quantity of manganese, such as the 12 per cent. in Hadfield's steel, has so powerful an effect in preventing the change from allotropic to  $\alpha$ -iron that it both suppresses the retardations and preserves, even during slow cooling, the hard, non-magnetic, allotropic condition, which in the absence of manganese is stable only at and above a red heat. Hence the hardness and unmagnetisableness of Hadfield's steel even when slowly cooled.

These facts, especially the unmagnetisableness of Hadfield's steel, support the allotropic theory. But note the new support which that theory gets from our second law. If it is through opposing an allotropic change that manganese confers the hardening power and gives Hadfield's steel its peculiar properties, and if the upper retardations be the ones chiefly connected with the allotropic change, then it is chiefly above the upper retardations that manganese should create the hardening power, and hence chiefly on cooling past those retardations as distinguished from Ar1 that the hardening power conferred by manganese should be lost. In other words, as the manganese increases, so should the loss of the hardening power at the upper retardations increase, which is part of our second law. In that this law thus agrees with this inference from the allotropic theory, it lends that theory some support.

But, while the second law thus agrees with either theory, the first law, though in perfect harmony with the allotropic theory, seems wholly unexplained by Professor Arnold's theory. Can the decomposition of a double carbide or iron and manganese at Ar2 explain how so large a fraction of the hardening power is lost there, when, as in Professor Arnold's steel, but an insignificant quantity of manganese is present? Can it explain why Professor Arnold's almost manganese-less steel loses as much of the hardening power at Ar2 as at Ar1?

In short, Professor Arnold's results, in that, jointly with mine, they point to the second of the above laws, do not oppose, but rather support, the allotropic theory, since that law harmonises with it closely; while in that they tend to confirm the first law, they support the allotropic theory, by showing that a law which it foretells, and which is not explained by any competing theory,

holds good of steel so widely different as his and mine. Obviously, when two pieces of evidence unite in common support of a law, the more diverse their sources, the more powerful is that support.\*

Looking now at the matter in a general way, the very fact on which Messrs. Hadfield and Arnold lay such stress, that manganese, like carbon, increases the hardening power, increases the intrinsic probability of the allotropic theory, as I will now try to explain.

Here let us recognise clearly two distinct facts, of which one points to allotropy, the other to carbon-condition as the cause of hardening.

The first is that not only does iron give strong indications of allotropy (1) in possessing two distinct states, a non-magnetisable and a magnetisable one, of which the former (when apparently preserved by sudden cooling) differs more from the latter (as obtained by slow cooling) than some distinct elements differ from each other; (2) in passing quickly at distinct critical points from one to the other of those states, changing from a non-magnetisable to a magnetisable substance, and simultaneously losing part, at least, of its power of being hardened by sudden cooling; and (3) in simultaneously undergoing, even when pure, a change of internal energy, which evolves heat and retards the rate of cooling; that not only is iron extraordinary in giving these indications of allotropy which distinguish it from the

\* His remarks in the last paragraph of page 202, and on page 203 (*Journal*, 1896, I.), are devoted chiefly to showing that my steel differs greatly from his in the shape of its cooling curve, the position of its critical points, and the absolute influence of sudden cooling. What inferences in addition to the second of the above laws should be drawn from these differences remains to be shown. To my mind, the striking thing is that his results return to the question at issue an answer like that of mine, in showing that much of the hardening power is lost at the upper retardations; that, necessarily unlike as are our steels in other respects, they agree in this essential feature. It was intrinsically probable that the presence of the large amount of manganese and silicon in my steel would affect markedly its thermal curves and the amount of its hardening power, though how much it would affect them could not be foretold. Hence it was probable that my steel would differ in these respects from a steel such as Professor Arnold has used. But this only makes it the more striking that they return like answers to the question at issue. A somewhat similar case would be that of two witnesses, each of unquestioned truthfulness—for he does not question the accuracy of my results—who, though differing in race, age, size, complexion, religion, politics, morals, temperance, self-control, and a thousand other irrelevant qualities, yet bore the same testimony with regard to a point at issue. Their differences in these irrelevant matters, far from lessening the value of the harmony of their testimony, clearly would increase it.

majority of elements; not only are these indications which it gives identified by direct experiment with the loss of the hardening power; but, so far as is shown, it stands alone in possessing that power.\* It would certainly be surprising if these two extraordinary things about iron, its allotropy and its hardening power, thus experimentally identified, were not in some way related. This certainly lends colour to the allotropic theory.

The second is, that the hardening power increases in rough proportion to the carbon-content, and especially that the condition of the carbon in hardened, *i.e.* suddenly cooled steel, appears to differ from that in the unhardened, *i.e.* slowly cooled metal. This certainly lends colour to the carbon theory.

Now comes the point which I wish to make. The degree of hardening induced by sudden cooling increases with the quantity of certain foreign elements present. The reason for this may be either, as the carbonists hold, that these foreign elements form strong, hard, high-temperature compounds which the sudden cooling preserves. This I venture to name the metamorphic rather than the carbon theory. Or, as the allotropists hold, that they retard the change from the allotropic to the normal state, so that in their presence a rapid cooling suffices to retain some of the allotropic iron. Each theory is reasonable in itself. If only one element, carbon, conferred the hardening power, it would be very reasonable to refer hardening to the preservation of a special high-temperature carbide, especially because the carbon in the suddenly cooled metal appears to be in a state different from that in which it exists in the slowly cooled metal. But the discovery that manganese, and perhaps other elements, confer this hardening power makes for the allotropic theory.

For while the carbon theory, that carbon forms a special, preservable, high-temperature, hard, strong, iron carbide, recognisable by a special chemical condition of the carbon, is reasonable enough as regards carbon alone; yet it is decidedly harder to believe that iron, the only metal which gives these extraordinary allotropic indications, should happen to form special preservable high-temperature, hard, strong compounds with *different elements independently* (manganese, &c.), and yet that the hardness and strength of these independent compounds should not be in some

\* We may expect that nickel and cobalt will be found to behave like iron.

way connected with this allotropy, in view of the facts (1) that, so far as is shown, no other metal forms any such compounds, *i.e.* possesses the hardening power; and (2) that the fact which lent colour to the carbon theory, viz. the apparent difference in chemical condition, between the carbon of hardened and that of unhardened steel, is lacking in case of manganese, for no such difference in the condition of manganese is shown.

I believe that we see two sides of one shield. The contention of the carbonists, or, if I may widen their name, the "metamorphists," that iron forms special high-temperature "metamorphic" compounds, which under some conditions are preservable by sudden cooling, is undeniable. It has never been denied. The contention of the allotropists should, I think, be that this metamorphism is dependent upon allotropy, or related to it; that allotropy is a primary cause of the metamorphism, though there may be others; that allotropy contributes to hardening indirectly by causing this metamorphism, and probably also directly and independently, through allotropic change in the ferrite, if not also in the iron of the composite minerals.

The proof of the existence of allotropy by the retardations in nearly, if not quite, chemically pure iron (Roberts-Austen), and by the simultaneous complete change of magnetic properties, seems complete. Its identification with these metamorphic changes by the fact that they accompany the allotropic retardations is strong (Osmond, Sauveur, the author). Its further identification with the hardening power, by showing that part of this power is lost simultaneously with these allotropic retardations (Professor Arnold, the author), and that nearly pure iron can be hardened to a degree not readily explained by metamorphism (Osmond, the author) is strong, though further evidence is certainly needed. The cumulative circumstantial evidence (Osmond, Roberts-Austen) pointing in the same direction is strong. Nevertheless, further and more cogent evidence concerning the preservation of allotropic iron is urgently needed. Evidence showing whether the properties of suddenly cooled steel, such as its coefficient of dilatation and its specific heat, are derived from or related to those of the apparently allotropic red-hot metal, would be most important.

The case is far from being closed. I fail to see, however, that

the evidence of Messrs. Hadfield and Arnold really opposes the allotropic theory, or, rightly considered, conflicts with my own.

*Alleged 65-ton and Related Errors.*—Professor Arnold charges me with "a mechanical error of 65 tons per square inch," and presents a table, one column of which is headed "Errors due to Mn. and Si., Tons per Square Inch." This charge from one whose official position should make it credible, and against one who values his own reputation for accuracy, is serious. Professor Arnold's words are, "*The maximum increase in hardness, due to quenching iron containing 0·21 per cent. of carbon, was not, as stated by Mr. Howe, 65 tons per square inch, but only 10 tons.*" The words which I here italicise are true, only in the limited sense of referring to steel containing 0·21 per cent. of carbon *and nothing else*. In his sentence just quoted, therefore, the words, "as stated by Mr. Howe," imply that I have asserted that iron containing 0·21 per cent. of carbon *and nothing else* can be strengthened by 65 tons per square inch by sudden cooling. But I have neither said, implied, nor supposed this; and this repeated charge of his appears to me without just foundation.\*

Let us see further whether his mode of presenting this charge is fair or fallacious. The sentence which I have just quoted derives its force from an implication that the tenacity of hardened steel wire containing 0·21 per cent. of carbon is a fixed and definite quantity, viz., 35 tons per square inch, which I have misstated as 99 tons; that hardening can increase the tenacity only by a fixed and definite quantity, viz., 10 tons, which I have misstated as 65 tons; and that these quantities are independent of the attendant conditions. But this implication is obviously most untrue, for the tenacity of the hardened bar, and the increase of tenacity which hardening will confer, depend greatly on the attendant conditions, such as the nature of the quenching bath, and the section of the piece hardened. Thus, by quenching some steel wire very kindly given me by Professor

\* So far as I can see, the only words of mine which can even be twisted into a suggestion to this effect, are the headings of Tables IV. and V. (*Journal*, 1895, II. 294–295). "Influence of Quenching Temperature on . . . Steel of 0·21 per cent. of Carbon." But first, this by no means implies, it should not even suggest, the absence of the elements which, in addition to carbon, are habitually present in steel; and, second, the explanatory note to Table IV. in its first two lines, calls attention to the presence of 0·31 per cent. of silicon, and 1·19 per cent. of manganese.

Arnold, almost identical in composition with the bars on which the experimented, and containing, by his own analysis—

Carbon.	Silicon.	Manganese.	Phosphorus.	Sulphur.	Aluminium.	Iron.
0·20	0·030	0·028	0·017	0·025	0·020	99·680

I raised its tenacity to no less than 59 tons per square inch. If now I were to adopt his style of reasoning, the comments which I could make on his results would parallel his comments on mine as follows:—

#### HOWE ON ARNOLD.

"The maximum increase in tenacity, due to quenching iron containing 0·20 per cent. of carbon, was not, as stated by Professor Arnold, 10 tons per square inch, but actually 35 tons. The actual maximum tenacity was not 35 tons per square inch, but 59 tons. The writer therefore concludes that Professor Arnold, in discussing a new theory involving the most delicate points in the molecular physics of steel, had founded his criticism upon his own initial mechanical error of 24 tons per square inch."

#### ARNOLD ON HOWE.

"The maximum increase in hardness, due to quenching iron containing 0·21 per cent. of carbon, was not, as stated by Mr. Howe, 65 tons per square inch, but only 10 tons. The actual maximum stress was not 99 tons per square inch, but 35 tons. The speaker therefore concluded that Mr. Howe, in proposing a new theory involving the most delicate points in the molecular physics of steel, had founded his deductions upon an initial mechanical error of 65 tons per square inch."

Now, if I said this, I should clearly utter a fallacy, and by juggling with words accuse Professor Arnold of an error which he has never made. Wherein is the fallacy? It is in ignoring the fact that Professor Arnold, in giving the above numerical measures, had in mind, and that every intelligent reader also would have in mind, that his numbers referred only to the precise conditions of his experiments. For a certain specific combination (or perhaps certain specific combinations) of quenching temperature, nature and temperature of bath, rapidity of motion in the bath, section of bar, and quantity of other elements present, his numbers are true; for all others false.

In like manner the maximum increase of 65 tons, and the maximum absolute tenacity of say 99 tons, which I reported, are

accurately true for my conditions, which were fully, clearly, and accurately set forth in an appropriate place. One of those conditions thus pointed out by me was the additional presence of 1·19 per cent. of manganese, and 0·31 per cent. of silicon. The fallacy in Professor Arnold's charge consists in his calling my results false, because, though accurately true for my conditions, including the presence of manganese and silicon clearly pointed out, they of course do not apply to other compositions to which no intelligent reader should suppose that they would apply.

Further considering the fairness of his presentation, we note that the phrase, "Mr. Howe, in proposing a new theory involving the 'most delicate points,' had founded his deductions upon an 'initial mechanical error of 65 tons per square inch,'" derives its force from the juxtaposition of the phrases "a new theory involving the most *delicate* points," and "an initial mechanical error of 65 tons." Is this juxtaposition fair? Does the needed delicacy aggravate, as this juxtaposition suggests, the alleged 65-ton error? Delicacy is needed, but it is delicacy of reasoning. To answer the question to which my investigation was directed, we needed to know whether there were *any* important discrepancy between the progress of the loss of the hardening power, and that of the carbon-change—loss of *any* important part of the hardening power at the upper retardations without corresponding change in carbon condition. I found that there was; so does Professor Arnold. The light which these investigations throw on the question before me depended not on the *exact size* of that discrepancy, but on the *existence* of some important discrepancy, so that the test needed was, in this sense, rather qualitative than quantitative. Delicacy in the tenacity determinations was not needed, though it existed. This juxtaposition, then, in that it suggests that the needed delicacy aggravates the alleged error, is fallacious.\*

\* Had I drawn any unwarranted inference from my data, this, while it would have palliated, would not have removed his mistake. An observation of a phenomenon in Nature is either true or untrue, and of one specific degree of accuracy. An error in applying it, or in drawing inferences from it, is an error in logic, not in observation, and cannot constitute or create a mechanical error, i.e. an error in the observation itself, which must ever remain of its initial truthfulness, no matter what inferences may be drawn from it. Had I drawn an unwarranted inference, he could justly have criticised my reasoning, but even then his charge of "a mechanical error" of 65 tons per square inch would have been wholly unjustified.

The column which he heads "Errors due to Mn. and Si." represents the differences between my accurate results, obtained under my clearly described conditions, and those which he obtains under purposely different conditions. They are not errors. He could justly have headed this column "Influence of Manganese, &c.," or "Difference due to Manganese, &c.;" but heading it "Error" is an unjust accusation.\*

To sum this up, the errors with which he charges me are not errors at all; they are the necessary differences between my accurate results, evidently applicable only to my clearly declared conditions, and his results obtained under purposely different conditions. His charge is aggravated both by fallacious suggestion, and by incorrectly calling the supposed error "mechanical;" whereas, had it been an error at all, it would have been one of reasoning.

*Definition of Allotropy.*—Modifying Faraday's definition,† I would define allotropy as "a change in the chemical and physical properties of an element, not explicable on purely mechanical grounds." This plan of definition has the merit of being based directly on the essence of the thing defined, the change of properties. It is not necessary to add "without change of chemical composition," because by definition an element cannot change its apparent ultimate chemical composition.

Professor Roberts-Austen's clear definition,‡ "A change of internal energy occurring in an element at a critical temperature unaccompanied by a change of state," while it would doubtless serve to distinguish most and perhaps all cases of allotropy, is open to the objection that it is based, not on the essence of the thing defined, viz., a change of properties, but on a cause, consequence, or concomitant, which, though it will doubtless generally and probably always accompany allotropy, yet conceivably may

\* Professor Arnold will see the injustice of this on examining his own words. Thus, he gives in his Table II. the results which he obtained with two lots of steel containing 0·21 per cent. of carbon. Of these, one was nearly free from other elements: the other had, like mine, much manganese and silicon. Now let him note that, when he comes to compare the results which he himself obtains with these two steels, he properly calls the differences between them not "errors" but "differences." They manifestly are not errors. But these differences are exactly parallel with those between my results and his own. They are not errors in his own case; how, then, can they be errors in mine?

† *Journal*, 1895, II. p. 261.

‡ *Ibid.*, 1896, I. 216.

not. His words are valuable, but I regard them rather as setting forth a means of detecting allotropy than as a definition.

Professor Arnold gives us not a definition but an example of allotropy. The case of oxygen-ozone is no more a definition of allotropy than a brick is the definition of a parallelopiped: in the former case we have no indication as to how far and in what respects a case may differ from the oxygen-ozone case without ceasing to be allotropy, just as in the latter we have no indication whether it is the rectangularity, ratio of axes, size, colour, hardness, history, or density of the brick that makes it a parallelopiped.

But if we correctly understand him that a change is not allotropic unless, as in that of oxygen-ozone, it be accompanied by a change in the number of atoms in the molecule, *i.e.* unless it be polymeric, his position seems untenable. Of isomerism, which is the allotropy of compounds as distinguished from elements, there are two well-recognised classes, "polymerism," or a change in the *number* of atoms in the molecule; and "metamerism," or a change in the *arrangement* of the atoms in the molecule; and there is no reason apparent why allotropy should not be of these two classes also. The mere discovery that the allotropy of oxygen is polymeric certainly does not prove, it should hardly suggest, that all other cases of allotropy must be, and that none can be metamic. We have as yet but scanty knowledge of the limits of allotropy, and it would be wholly premature to assert, even of all those cases which have been studied, that they are all polymeric as distinguished from metamic, or indeed to insist that all cases are either polymeric or metamic, as we now understand those words. The existence of allotropy we know; as to its causes we now speculate, often from incomplete data.\*

To these two classes of allotropy we may add a third. What we call elements may not be true, but only apparent elements, merely yet unresolved compounds of the true elements. Allo-

\* Nernst, "Theoretical Chemistry," Palmer, 1895, p. 236. "We do not certainly know the reason for the difference between the allotropic forms of solid elements, but the probability, in the light of the atomic hypothesis, is very strong, that the atoms unite either with a different number in the molecule, or with a different mode of union. To be sure, certain proof for this supposition is wanting at present, since hitherto it has been impossible to obtain a glimpse into the molecular constitution of solids."

tropy of an apparent element may in certain cases be due to a variation in the grouping of the true elements. It may, in short, be metamicric isomerism.

Much of the opposition to the allotropic theory seems to spring from a narrow view of what allotropy is. There seems to be a disposition on the part of those who oppose this theory to narrow unjustifiably the meaning of allotropy, and to reject the theory because it will not fit this narrowed meaning. That the established meaning of allotropy is broad and generic is shown, not only by the definitions to which I have just referred, by Faraday and Roberts-Austen, the latter endorsed apparently by such illustrious chemists as Van't Hoff and Ostwald, but by the remarks of Lothar Meyer,\* Wanklyn,† and even of Berzelius himself, the coiner of the word.‡

*Preservation of Allotropy in Combination.*—Professor Arnold appears to assert that the idea "that an element may preserve its allotropic identity after combination with another element, to form a compound, would, if the data upon which it was founded were sound, startle the pure chemical world": elsewhere (p. 202) he calls it "a startling theory;" and he asserts that "the existence of an attenuated carbide of an allotropic modification of iron is (was) a theory opposed to *all known chemical laws*."§ Passing by the self-refuting assertion of this last clause (it is about as impossible that a single idea should break all known chemical laws as that a criminal could by one act break all known statutes; and, indeed, while the idea criticised might

\* *Journal*, 1895, II. p. 264.

† Professor J. A. Wanklyn in Watt's "Dictionary of Chemistry," iii. p. 423, 1875. "As before remarked, the instances of inorganic isomerism are usually called instances of allotropy—isomeric substances and allotropic substances being nearly equivalent expressions. Inorganic compounds, such as the various forms of silicic acid, of sesquioxide of iron, of sesquioxide of chromium, of alumina, must be classed among substances affording examples of isomerism."

‡ See footnote to p. 215.

§ Since writing the above, I have been given to understand that, by the expression "opposed to all known chemical laws," Professor Arnold means that when an allotropic element forms a compound, that compound has the same properties whether formed from the  $\alpha$  or the  $\beta$  state of that element; which is equivalent to saying that no case of the preservation of allotropic identity after combination has yet been proved. I should hardly have thought that this was adequately expressed by the words "opposed to all known chemical laws." There are plenty of things not yet proved which nevertheless are not opposed to the laws of science. We shall shortly see whether this particular thing is actually without parallel.

be opposed to *theories*, it is not easy to see how in the nature of the case it could be opposed to *laws*):—passing this by, let us ask whether my idea is novel, for if not, how is it to be startling? and whether it is opposed to our present theoretical views.

*Novelty.*—Berzelius, whom we may call the father of allotropy, not only set this very idea forth, at least as early as 1845, but gave specific instances of the existence of phosphorus in its different allotropic conditions in its sulphides, which, he said, gave this idea a high degree of certainty,\* and actually asserted that the cause of a certain class of isomerism must necessarily be the preservation of allotropic identity after combination.

Cizancourt, in 1865, asserted the preservation of the allotropic conditions of iron in the oxides, sulphides, and carbides of that metal.†

\* *Traité de Chimie*, Berzelius, Esslinger, and Hoefer, 1845. After saying, on page 21, “The second kind of isomerism is of a different nature. Several elementary bodies have the strange property of taking on, under the influence of certain circumstances which are not yet determined, a different external state or different forms; they seem to preserve these forms in several combinations, and can then cause the difference of the properties of the combinations. . . . We have not yet succeeded in giving a satisfactory idea of the cause of this difference of the properties of elementary bodies; but we shall designate this fact by the name of allotropy. . . .” He goes so far as to maintain, on page 22, that “In the case of isomeric states of compounds, which, for example, contain only two elements, in which one atom of one is combined with one atom of another isomerism cannot arise from a different order of juxtaposition of the atoms, it must have allotropy for its cause.”

On page 829 he says: “On comparing the red combinations of phosphorus which have just been described with the corresponding liquid combinations, and these two kinds of combinations with phosphorus as well in the common state as in the red allotropic state, we shall find that the opinion enunciated above as to the combinations of phosphorus acquires a high degree of certainty. According to this opinion, phosphorus exists in one of these groups of compounds in the ordinary state, in the other in the red state, and these isomeric modifications depend upon the different allotropic states in which the radicle exists, in conformity to what I have said on pages 21 and 22, as to allotropy in general. But here we are permitted to recognise, with considerable certainty, in which of the two allotropic states the radicle exists in the combination.” (The italics throughout are mine.)

+ *Comptes Rendus*, lxi. pp. 578, 706, and 1865. Commissaires of this paper, Chevreul, Regnault, and Fremy. On page 579 he says: “Berzelius has already been led to class the above compounds of iron [the ferrous and the ferric, H. M. H.] by referring them to two chemically distinct metals, to which he had given the names ferrosum and ferricum. It remained to find out whether these metals had a real physical existence, and could be found distinct in metallurgy. The discovery of the allotropic states has succeeded in fixing our ideas concerning the property which at least several bodies possess of having, though with the same ultimate chemical composition, very different conditions, with special characteristics, which they can preserve even when undergoing certain transformations or combinations.”

Page 581 he says: “It is, moreover, necessary to remark that magnetic iron oxide

It is notorious that Brodie believed that carbon preserved the allotropic condition of "graphon" (which he wrote Gr.), in graphitic acid, which he wrote  $\text{Gr}_4\text{H}_4\text{O}_5$ , and in the graphitates; and these symbols have wide use.\* This case is really famous; it is thought so important that, to my knowledge, it is set forth at least at one American university in the lectures even to the undergraduates in the academical department. If it be taught even to those, most of whom are not to be men of science at all, can it have so far escaped the knowledge of "pure chemists" that they can be "startled" by the enunciation of a parallel case?

In 1894 D. Berthelot appears to think that the researches of his illustrious father supports Brodie's contentions, for, after putting the question "Can it (allotropy) resist combination, so that the allotropic states may furnish two series of distinct compounds," and pointing out the difficulty in actually demonstrating this retention of allotropic identity, he appears to reach an affirmative conclusion, relying in large part on "the capital facts discovered by Brodie and Berthelot concerning the graphites and the compounds derived from them."†

I understand that Brodie's belief, though it needs further support before it can be held firmly, yet is widely accepted provisionally as a reasonable explanation of the phenomena; and all that we need for our present purpose is that it is thought reasonable.

Coming even closer to our present question, D. Berthelot

and magnetic pyrites have, like hardened steel, permanent magnetism. This property, common to natural and artificial substances, whether in the state of oxide or sulphide or of carbide, can result only from the simultaneous presence of the two allotropic states of iron which are the sole common component of these bodies so different."

However much we may differ from his conclusions as to his actual discovery, isolation or identification of these allotropic forms, his words, presented under the patronage of the three eminent chemists above named, show that the idea of the allotropy of an element in its compounds is neither novel nor startling.

\* Ann. Ch. Pharm., cxiv. 6. See Watt's "Dictionary of Chemistry," 1874, i. p. 758, and ii. p. 941; Wurtz, "The Atomic Theory," 1881, p. 129, &c., &c.

† "The graphites, in effect, submitted to the action of an oxidising agent, give for each variety of graphite special graphitic oxides, which the other compounds of carbon do not furnish. Each of these graphitic oxides produces special derivatives which regenerate it, and it is only by a much more profound oxidation that all are brought to the state of carbolic acid."—*De l'Allotropie des Corps Simples*, par Daniel Berthelot, Professeur agrégé à l'École Supérieure de Pharmacie de Paris, Assistant au Muséum, pp. 3 and 4, 1894; Paris, G. Steinheil.

seems to hold that iron preserves its allotropic identity in its oxides.\*

Now, each of these chemists may be mistaken in supposing that allotropy actually is preserved in these individual combinations; in fact, the evidence in support of the views of Berzelius as to the preservation of the allotropic states of phosphorus is generally thought insufficient; and, for that matter, I do not think any case of such allotropic preservation has been absolutely demonstrated. But however this may be, these opinions, dating as they do from 1845 to 1894, prove that the idea is not novel, and indicate that it is reasonable. We can hardly suppose that these chemists would give these opinions if they were really opposed to the laws of chemistry.

*Harmony with Chemical Theories.*—For many the weight of the opinions which have just been given will suffice to show that this idea cannot be in discord with our chemical theories; but for those who are reluctant that their judgment should submit even to such authority, it may be well to look further.

Be it understood that the preservation of allotropy in combination, like the preservation of isomerism, implies, not necessarily that the atomic grouping of the compound or derivative is the exact reproduction of that of the allotropic or isomeric parent, though for brevity we often speak as if it were; but that it corresponds to that of the parent, or is related to it. A "carbide of  $\beta$  iron" means a carbide in which the grouping of the iron atoms is related to or corresponds to the specific grouping of those atoms which occur in  $\beta$  iron. It is in this sense that I shall speak of the preservation of allotropy and isomerism in combination.

First, very early in his study of chemistry the student is familiarised with the idea that certain groups of atoms, such as ammonium  $\text{NH}_4$ , hydroxyl  $\text{OH}$ , sulphuryl  $\text{SO}_2$ , &c., persist, i.e. pass undecomposed, and thus with preservation of their

\* "These allotropic modifications of iron perhaps persist in its compounds, for M. Moissan, in studying the oxides of iron, has noticed that they undergo profound modifications in the neighbourhood of 700 (dark red), and in the neighbourhood of 1000 (white red). These are exactly the temperatures indicated by Pionchon (for the allotropic points of metallic, i.e. free iron). Comparing these facts with those observed in regard to free iron, we are led to think that this metal preserves the faculty of changing its state even in its oxides."—*Ibid.*, p. 69. (The italics are mine.)

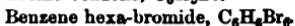
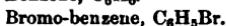
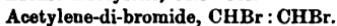
identity, and in a measure as distinct entities, through chemical changes, from one chemical compound into another. Thus in this reaction



the  $\text{NH}_4$  has been written in this particular way so as to indicate that the ammonium preserves its identity,\* or at least that the ammonium type of atomic grouping survives the change from the chloride to the nitrate state. So we write that sulphuric

acid  $\text{SO}_2 \begin{cases} \text{OH} \\ \text{OH} \end{cases}$  yields sulphuryl oxichloride  $\text{SO}_2 \begin{cases} \text{Cl} \\ \text{OH} \end{cases}$ , to indicate that in these substances the sulphur and oxygen exist linked together as sulphuryl,  $\text{SO}_2$ , and the hydrogen and oxygen as hydroxyl,  $\text{OH}$ ,† or at least that the atomic grouping of these radicals is the same in the sulphuryl oxichloride as in the sulphuric acid, and thus survives the destruction of the sulphuric acid in which they first occurred.

Next, of the group of atoms which we thus regard as retaining their relations to each other as a group, in the compounds which contain them, and as surviving chemical changes of those compounds, there are many sets which are isomeric. Thus, though acetylene and benzene are isomeric (both polymeric and metamerous), *i.e.* of the same percentage composition, yet we suppose that their special types of atomic grouping persist and recur in their compounds; and the symbols of those compounds are sometimes so written as to indicate this view. Thus we may write:



so as to indicate that in these acetylene compounds the atomic grouping is of the acetylene type, while in these benzene compounds it is of the benzene type, and thus that these two types survive chemical combination with other bodies.

Next we have isomeric substances, the compounds of which are not only parallel but actually isomeric, *i.e.* of identical ultimate composition yet different properties, inheriting the special structural arrangement and the corresponding properties of the

\* Cooke, "Chemical Philosophy," 1875, p. 38.

† Remsen, "Theoretical Chemistry," 1897, p. 122.

isomeric parents. This is true in the case of acetylene dibromide and benzene hexa-bromide just given. Again, to take a metameristic case, "the two alcohols, normal propyl,  $\text{CH}_3\text{CH}_2\text{CH}_2\text{OH}$ , and isopropyl or pseudopropyl alcohol,  $\text{CH}_3\text{CHOH.CH}_3$ , are the starting-points for the preparation of the two series of isomeric propyl compounds."\* *E.g.* from the former is derived chloro-propyl alcohol,  $\text{CH}_3\text{Cl.CH}_2\text{CH}_2\text{OH}$ , and from the latter chloro-iso-propyl alcohol,  $\text{CH}_3\text{CH}(\text{OH}).\text{CH}_2\text{Cl}$ , which are isomeric (metameristic), yet believed to be distinct. We sometimes write the chemical symbols as I have here done, in order to illustrate the view that these two characteristic atomic groupings of the two propyls are retained, not only in their alcohols, but in the derivatives of those alcohols.

So dextro- and laevo-tartaric acid are of identical ultimate composition, and thus isomeric. They differ from each other right and left in crystalline form, optical rotary power, and pyro-electricity; and they transmit these differences to their respective metallic salts, which, though isomeric, differ from each other right and left in these three properties.

Coming, finally, to a case very close to the present one, Moissan reported that each of the two isomeric ferrous oxides yielded on further oxidation the corresponding modification of magnetic oxide. He calls these latter  $\alpha$  and  $\beta$  varieties of magnetic oxide,  $\text{Fe}_3\text{O}_4$ .†

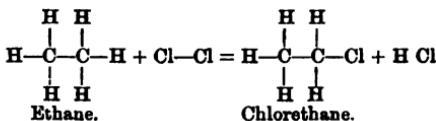
It is thus completely in harmony with our present views, not only that definite atomic groupings, but even definite isomeric groupings may preserve their identity in passing through chemical changes, and may persist in the compounds of the isomers, even when these compounds themselves are isomeric. Indeed, we may say that our theories are in part based on this conception of the preservation of specific groups, including isomeric ones, in combination. In view of this, it is hard to see how they can be opposed to the preservation of allotropy in combination; for

\* Ramsen, "Principles of Theoretical Chemistry," 1897, p. 202.

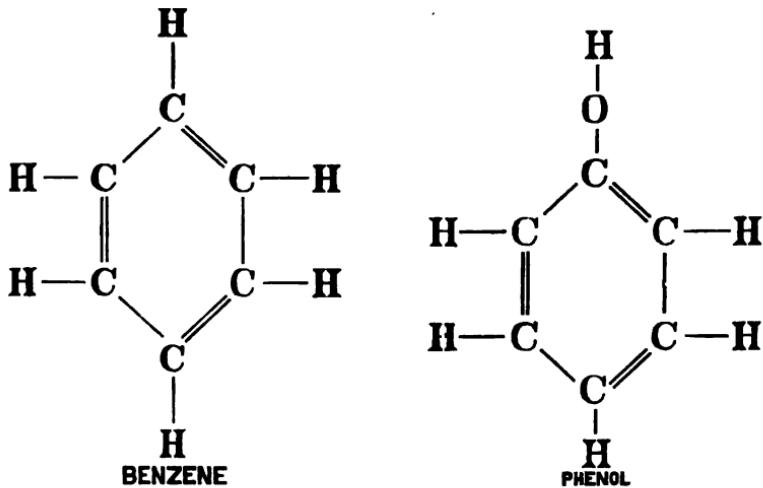
† *Ann. Chim. Phys.*, 5, xxi., 1880, p. 229. "Ainsi l'on voit cette curieuse propriété du sesquioxyle de fer, de donner des variétés allotypiques, s'entendre non seulement à l'oxyde magnétique, mais encore au protoxyde. Et, chose logique à concevoir, les deux variétés de protoxyde de fer pourront fournir par leur combustion les variétés correspondantes d'oxyde magnétique. Les qualités spéciales acquises par le premier corps, grâce à une élévation du température, se retrouveront encore dans le produit secondaire qu'il formera après une nouvelle oxydation."

each is the preservation of specific groupings of atoms identical in ultimate composition, with the sole difference that isomerism relates to unlike, allotropy to like atoms.

Now it is hard to see how this difference can change one of the foundations of our theories into something opposed to them; for the preservation of specific groupings of like atoms, far from being opposed to our theories, also forms an important part of their foundation. Thus a common explanation of variation in valence is that it is due to varying linkage of the atoms of one and the same element. For instance, the constitution of ethane and chlorethane has been represented thus:—



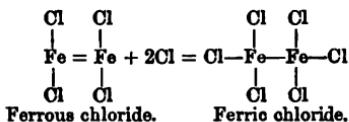
and that of benzene\* and phenol has been represented thus:—



Here we conceive, among other things, that the atoms of carbon in ethane and chlorethane are linked together by single

\* Of this benzene formula it is said: "If we could devise no other formula for benzene, we should be obliged to accept it. As a matter of fact, it is now almost universally adopted; not so much on its intrinsic merits as on account of the enormous service which it has rendered to chemistry."—*Watt's Dictionary of Chemistry*, i. p. 452, 1888.

linkage, while in benzene and phenol they are linked in a peculiar chain; and we here further conceive that these two distinct types of linkage persist through the reactions which change ethane into chlorethane, and benzene into phenol.\* Again, the existence of ferric and ferrous chlorides is sometimes explained by writing them thus:—



so that in the ferrous salts we here conceive a special linkage, or special grouping, of the iron atoms among themselves, and we hence conceive that this special grouping of the iron atoms among themselves can survive chemical change ; as, for instance, when one ferrous salt is converted into another.

In short, we conceive in both these cases that a certain peculiar grouping or linkage of like atoms among themselves survives chemical change.

Now, while opinions differ as to just what the specific grouping of the carbon atoms is, which in this or that particular case is preserved in combination, yet that these specific groupings of these like atoms are in such cases preserved in the sense that this grouping in the parent is related to this grouping in the derivative, is generally received as an important part of our theories.

I do not say that this particular preservation of specific groupings of like atoms is the preservation of allotropy, though, indeed, it is analogous to it. What I say is this: (1.) Our theories recognise distinctly the preservation of isomerism in combination. (2.) The preservation of allotropy in combination differs from this only in being the preservation of specific groupings of like instead of unlike atoms. (3.) But this difference

\* "The other hydrocarbons of this (the benzene) series may be regarded as containing the same group of carbon atoms as benzol, and as derived from it by replacing one or more of its hydrogen atoms with the radicals methyl, ethyl, or amyl. It is evident that, by replacing several atoms of hydrogen with methyl, we should obtain a body of the same composition as by replacing a single atom with a radical richer in carbon, and we have abundant evidence that compounds thus obtained, though isomeric, are not identical."—*J. P. Cooke, jun., Chemical Philosophy*, 1875, p. 482.

cannot create a discord with our theories, for these theories recognise the preservation of specific groupings of like atoms.

Indeed, while I can readily understand that those who have not closely followed this question should think the preservation of allotropy in combination a superfluous idea, yet that any one should think it in discord with theory is to me most surprising.

A word as to Professor Arnold's mode of presentation. He says: \* "To carry this idea to its logical but absurd conclusion, it might be urged that the non-poisonous properties of  $\text{CO}_2$  were due to the fact that in it the oxygen existed in the diatomic form, whilst the actively poisonous properties of CO were due to triatomic oxygen."

It is not a logical inference from the idea that allotropy is preserved in one individual combination that it must be in all. It is not absurd, though perhaps needless, to attribute the toxic difference between carbonic oxide and acid to allotropy. Nef, indeed, insists that the poisonous properties of carbonic oxide are due to the bivalence of its carbon, and he cites other violently poisonous compounds which, in his opinion, contain bivalent carbon.<sup>†</sup> I will not say that this bivalence is the preservation of allotropy, though it is something parallel with it.

Professor Arnold's presentation thus is fallacious.

*To sum up:* Professor Arnold's positive assertion that the preservation of allotropy in combination is "opposed to all known chemical laws" on examination breaks down completely. The idea appears wholly in accord with our chemical theories, and many chemists, some of the most illustrious, have proclaimed specific instances of this preservation, at least one of which is now widely, if not generally accepted. Moreover, his presentation of the case is fallacious.

\* *Journal*, 1896, I. p. 201.

† In this connection, see *Proceedings of the American Academy of Arts and Sciences*, New Series, xix. p. 102, 1893, and xxii. p. 151, 1895: "Among the constantly increasing compounds of carbon, there is but one substance in which the presence of a bivalent carbon atom is pretty generally accepted, and which is always put forward as the sole exception to the otherwise constant tetravalence of this element, namely, carbonic oxide."

Mr. Nef goes on to show that in prussic acid and certain other carbon compounds the carbon is bivalent, and in a private communication he confirms the inference that he refers these poisonous properties to the bivalence of the carbon. I do not say that his idea is right, but that it is certainly far from absurd.

But to this feature of the carbo-allotropic theory I attach relatively little weight. The important thing is that both allotropy and carbon-condition appear to be primary causes of the hardening of steel.

*The jog.*—An eminent correspondent has privately questioned my assertion \* that the jog occurs in the stress-strain diagrams of copper and of certain alloys. Mr. G. C. Henning authorises me to say that he finds well-marked jogs in both of these cases.

I learn, on further inquiry, that soft steel which has been strained through and past the jog, may nevertheless again show a jog when re-tested.†

I now sum up this whole reply, first referring my readers to its opening paragraph.

(1.) The evidence offered in rebuttal by my critics does not oppose my own.

(2.) Mr. Hadfield's objections to the thinness of my specimens, his suggestion that they may have absorbed carbon, and that their strengthening may be superficial or due to stress, all seem untenable. His objection that their strengthening may be due to their manganese is met by my later results, which go to show that steel with even less carbon and with no manganese is much strengthened by quenching.

(3.) Professor Arnold's evidence, considered in connection with my own, does not oppose, but rather tends to support the allotropic theory.

(4.) The errors with which he charges me have no real existence.

(5.) Not only is the preservation of allotropy in combination completely in harmony with our theories, but many chemists, some of them illustrious, have announced specific cases of such preservation, and one case of it is very widely, if not indeed generally, accepted.

\* *Journal*, 1895, II. p. 269.

† *Ibid.*, p. 288; see a paper by Professor Thomas Gray, "The Yield-Point of Iron and Steel," Hartford, May 28, 1897, meeting of the American Society of Mechanical Engineers.

## THE INFLUENCE OF PHOSPHORUS ON COLD-SHORTNESS.

BY THE BARON HANNS JÜPTNER VON JONSTORFF.

IT is a well-recognised fact that the influence of the same proportion of phosphorus on the cold-shortness of different varieties of iron differs very considerably. Apart from pig iron, in which, according to the nature of its use, cold-shortness can be of less moment, steel and all kinds of ingot iron are in this respect very sensitive. Hard finery iron is less sensitive, and soft finery iron is still less so, but the least affected is soft puddled iron. Whereas, according to Peter Ritter von Tunner,\* Bessemer Gold Medallist of the Iron and Steel Institute, in the case of the best hard varieties of steel, analysis shows only 0·01 to 0·02 per cent. of phosphorus; with 0·03 to 0·06 per cent. steel is considerably inferior, although finery iron containing 0·2 to 0·3 per cent. is still of good quality, and puddled iron, which has been found in practice to be serviceable, has been known to contain 0·5 per cent. and upwards.

In order to explain this phenomenon, Richard Åkerman, Bessemer Gold Medallist of the Iron and Steel Institute, has cited the fact that all cold-short varieties of iron, like burnt iron, exhibit a coarsely crystalline, laminated, and highly lustrous fracture, and that their low tensile strength can be ascribed to their crystalline texture. Inasmuch as steel, on account of its higher percentage of carbon, is more inclined to crystallisation, a slight proportion of phosphorus suffices to render it coarsely crystalline. All cast and ingot steels, and even ingot iron, thanks to the fluid condition in which they were during their production, tend to crystallise, especially if slowly cooled, and consequently they are more sensitive to the influence of phosphorus, which also facilitates the formation of crystals. A prolonged heating of iron similarly induces crystallisation, and with it cold-shortness, as is shown

\* *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, 1887, vol. xix. p. 227.

by burnt iron, the action being the more rapid and complete the higher the temperature employed. Suitable mechanical treatment of the iron eliminates laminated coarsely crystalline texture, and this is done the more easily and better the less phosphorus and carbon it contains.

Against this theory, which is in good accord with experience, Professor B. W. Cheever \* prefers to regard this variation in the action of the same proportion of phosphorus on different varieties of iron and steel as being due to the phosphorus occurring in two distinct forms, as phosphide and as phosphate, the latter being in the admixed slag. Although this undoubtedly is the case, and although it must be conceded that an explanation of the behaviour referred to seems at first sight to be in part assisted by it, it is, however, as Leopold Schneider † has exhaustively shown, altogether inadmissible, inasmuch as the analytical methods employed by Cheever are not above criticism, and, moreover, as the proportion of phosphorus represented by the slag enclosed in the puddled steel can hardly exceed 0·002 per cent. of the weight of the steel, a proportion which, by the side of the harmless total proportion of phosphorus of 0·3 per cent., is absolutely insignificant. Several years ago the author ‡ himself endeavoured to arrive at a solution of this problem.

It is a well-known fact that pig irons, at any rate varieties rich in phosphorus, when dissolved in dilute acids, give off, besides hydrogen, hydrocarbons, &c., phosphuretted hydrogen ( $H_3P$ ), which can easily be recognised by its characteristic odour. It has also long been known that when different varieties of iron are dissolved in hydrochloric acid an insoluble residue is left, which may contain silica, graphite, titanic anhydride, chrome iron, iron phosphide, and iron carbide. Leopold Schneider § succeeded in isolating the easily fusible phosphorus compound by means of an aqueous solution of copper chloride, which acts but very slightly on iron phosphide, whilst it rapidly dissolves both pure iron and iron alloys. The varieties of pig iron employed in the investigation were: spiegeleisen (*a*), white pig iron (*b*, *c*),

\* *Transactions of the American Institute of Mining Engineers*, vol. xv. p. 448.

† *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, 1887, vol. xxxi. p. 361.

‡ *Ibid.*, 1894, vol. xvii. pp. 209.

§ *Ibid.*, 1886, p. 736.

1897.—i.

grey pig iron (*d, e*), white pig iron (*f, g*), and ferromanganese (*h*), having the following compositions:—

	<i>a.</i>	<i>b.</i>	<i>c.</i>	<i>d.</i>	<i>e.</i>	<i>f.</i>	<i>g.</i>	<i>h.</i>
Combined carbon . . . .	3·3	...	3·56	...	0·55	...	3·98	5·28
Graphite . . . .	...	...	...	2·2	2·85	...	...	...
Phosphorus . . . .	2·5	1·45	0·53	1·48	0·94	3·01	3·4	0·13
Silicon . . . .	0·06	...	0·07	4·0	1·8	0·46	0·89	trace
Manganese . . . .	0·2	...	2·47	trace	0·07	4·33	18·15	28·7
Sulphur . . . .	9·44	...	0·028	trace	0·01	trace	...	trace
Copper . . . .	...	...	0·03	trace	0·01	trace	...	trace
Titanium . . . .	...	...	...	0·15	...	...	...	...
Iron . . . .	...	...	...	...	...	...	...	65·8

The insoluble residue contained:—

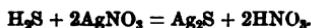
	<i>a.</i>	<i>b.</i>	<i>c.</i>	<i>d.</i>	<i>e.</i>	<i>f.</i>	<i>g.</i>	<i>h.</i>
Iron . . . .	100	100	100	100	100	100	100	100
Phosphorus . . . .	18·6	18·6	18·2	18·2	18·5	20·5	37·7	38·8
Manganese . . . .	...	...	...	...	...	5·7	52·8*	54·4

All varieties of pig iron when treated with copper chloride leave, if manganese is not present in large quantities, iron phosphide of the composition  $\text{Fe}_3\text{P}$ . If, however, manganese is present in considerable quantities, the proportion of phosphorus rapidly increases with that of manganese in accordance with the formula  $\text{Mn}_3\text{P}_2$ . In the varieties of pig iron examined the iron phosphide was found only as a pulverulent crystalline admixture, whilst the ground-mass forming the texture was poor in phosphorus. Thus the phosphorus favours the formation of crystals in the less easily fusible constituents of the iron by the formation of easily fusible compounds, whilst these, being the last to solidify, do not separate out in large crystalline planes. A similar method of combination of phosphorus was also detected by the author in steel and weld iron.

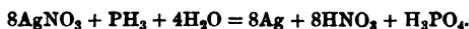
He next endeavoured to find another method by investigating the gases evolved. The gases were passed through two Peligot tubes with a neutral solution of silver nitrate of known strength. The current of gas was regulated by means of an aspirator. The reactions taking place are the following:—

\* Silicon 0·7.

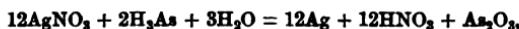
The sulphuretted hydrogen given off forms silver sulphide according to the equation :



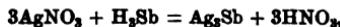
Whilst the phosphuretted hydrogen gas decomposes the silver solution with the formation of phosphoric acid and the deposition of metallic silver :



As arseniuretted hydrogen acts in a similar manner to phosphuretted hydrogen,



and antimony hydrogen also acts on silver solution,



the sample of iron in question must be previously tested for arsenic and antimony. The solution of silver nitrate employed must not be ammoniacal, as if acetylene should chance to be present among the hydrocarbons given off, acetylene silver would be precipitated. Thus the precipitate in the silver solution thrown down by the gases given off on dissolving the sample of iron in dilute hydrochloric or sulphuric acid, consists of silver sulphide and metallic silver. On filtering the silver solution through glass-wool, and titrating the silver contained in the solution by ammonium sulphocyanide according to Volhard's method,\* the difference gives the sum of the metallically precipitated silver and the silver combined with sulphur. On treating with dilute nitric acid the residue remaining on the filter and adhering to the sides of the Peligot tube, the metallic silver is alone dissolved, which is then similarly titrated with ammonium sulphocyanide, whilst the silver sulphide remains undissolved and may be determined by difference. Inasmuch as, according to the equations given above, eight atoms of silver represent one atom of phosphorus, and two atoms of silver one atom of sulphur,

$$1 \text{ part by weight of silver represents } \frac{31}{8 \times 108} = 0.0359 \text{ part by weight of phosphorus,}$$

$$1 \text{ part by weight of silver represents } \frac{32}{2 \times 108} = 0.148 \text{ part by weight of sulphur.}$$

Owing to the fact that the sulphur contents of a sample of iron is not in all circumstances completely given off as sulphur-

\* *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, 1880.

retted hydrogen by dilute acids, a few results of sulphur determinations by this method, which for the above reason deserves full investigation, may not be out of place:—

Sample.	Total Sulphur determined Gravimetrically as Barium Sulphate.		Sulphur Contents of the Sulphuretted Hydrogen evolved on Treatment with Dilute Sulphuric Acid (Sp. Gr. 1·1).
	No.	Per Cent.	
1	0·066	0·0711	
2	0·025	0·0099	
3	0·050	0·0289	
4	0·029	0·0284	
5	0·282	0·2795	

For the phosphorus determinations communicated in this paper, as for the above sulphur determinations, dilute sulphuric acid of 1·1 specific gravity at 18° C. was employed for dissolving the metal. The solution was begun in the cold, the temperature was then raised to boiling, and, lastly, when the solution was complete, air was drawn for some ten minutes through the apparatus. The silver solution, of which each of the two Peligot tubes held 20 cubic centimetres, contained 0·00924 gramme of silver per cubic centimetre.

Owing to the fact that on the decomposition of the silver solution by sulphuretted hydrogen, as also by phosphuretted hydrogen, nitric acid is formed, the latter must, in spite of its great dilution, in the course of time have a dissolving action on the precipitated metallic silver. This is shown by the subjoined figures, which were obtained from one and the same sample. The titration of the metallically precipitated silver was effected after very different intervals of time after the completion of the solution. The silver contents are expressed in percentages of the weight of the sample.

The Titration was Effected :	Silver.	Equivalent to Phosphorus.
Immediately after solution . . . . .	Per Cent.	Per Cent.
6 hours after solution . . . . .	0·4749	0·01705
12 hours after solution . . . . .	0·3883	0·01322
72 hours after solution . . . . .	0·3188	0·01127
	0·2318	0·00832

These figures show, however, that the error in the phosphorus determination, due to the redissolving of the reduced silver, is fairly inappreciable if the titration is effected quickly after the precipitation. The quantity weighed out varied from 0·6 to 0·3 gramme.

In the following table some results obtained by the method described are recorded :—

No.	Carbon per Cent. by Weight.	Phosphorus per Cent. by Weight.	Grammes taken.	Silver Precipitated by H <sub>3</sub> P in per Cent. of Sample.	Phosphorus per Cent.			Remarks.	
					Undissolved.				
					Given off as H <sub>3</sub> P.	By Dif- ference.	Deter- mined Gravi- metrically.		
1	2·385	0·1315	0·6521	0·7324	0·0263	0·1052	...	A. Pig irons.	
2	3·418	0·0744	1·7117	0·0733	0·0026	0·0718	0·0725	White pig iron.	
3	3·418	0·0744	0·7660	0·1604	0·0058	0·0636	...	Dark grey pig.	
4	2·296	1·048	0·3375	1·0679	0·0383	1·0097	...	Dark grey pig, dissolved in sulphuric acid diluted with equal volume of water.	
								So-called "Panzerguss" for fire-bars.	
5	0·2254	0·0970	0·6036	0·1516	0·0054	0·0916	0·0906	B. Wrought iron and steel.	
6	0·1800	0·0598	0·6895	0·0550	0·0020	0·0576	...	Short.	
7	0·1510	0·0690	1·3583	0·0333	0·0012	0·0638	...	Short.	
8	0·239	0·1010	1·5253	0·0005	...	0·1010	0·1120	Good material.	
9	0·259	0·0860	1·7266	0·0404	0·0015	0·0845	...	Good material.	
10	...	0·0984	1·6557	0·4514	0·0162	0·0802	0·0789	Very short.	
11	0·273	0·0469	2·4316	0·1504	0·0064	0·0415	...	Slightly cold-short.	
12	0·308	0·1242	2·6820	0·6758	0·0243	0·0999	...	Cold-short.	
13	0·343	0·5649	2·0424	0·6902	0·0248	0·5401	...	Cold-short.	
14	0·122	0·6212	3·0188	0·5002	0·0190	0·6022	...	Cold-short.	
15	0·375	0·0847	2·7547	0·4749	0·0171	0·0676	...		
16	0·217	0·0677	2·0870	0·5147	0·0184	0·0493	0·0487		
17	0·168	0·0704	5·6423	0·4932	0·0177	0·0527	0·0539		
18	0·137	0·0648	5·5673	0·6074	0·0218	0·0370	...		
19	0·220	0·0829	1·9924	0·6065	0·0218	0·0611	0·0617	Increasing in cold-shortness.	

The results recorded in this table, especially in the case of Nos. 15 to 19, show that as the cold-shortness increases, so too does that proportion of phosphorus which is given off as phosphuretted hydrogen when the material is treated with dilute acids.

Whilst, for example, Nos. 8 and 9, with a total phosphorus contents of 0·101 and 0·086 per cent., which yield only 0 and 0·0015 per cent. of phosphorus as phosphuretted hydrogen, represent excellent material without a trace of cold-shortness, samples Nos. 11, 15, 16, 17, 18, and 19, with the lower total

phosphorus contents, and considerably so in some cases, of 0·0469, 0·0847, 0·0677, 0·0704, 0·0648, and 0·0829 per cent., exhibit distinct, or even very considerable, cold-shortness. They, however, on being dissolved in dilute acids, yield far more phosphorus as phosphuretted hydrogen than the samples previously referred to, namely, 0·0054, 0·0171, 0·0184, 0·0177, 0·0218, and 0·0218 per cent.

Samples 5, 6, and 7, too, which exhibit distinct shortness, have in part a smaller total phosphorus contents than the samples 8 and 9 representing excellent material, namely, 0·0970, 0·0596, and 0·0690 per cent. The phosphorus contents evolved as phosphuretted hydrogen is, however, so small, 0·0054, 0·0020, and 0·0012 per cent., that the cold-shortness of these materials cannot well be deduced from this.

The explanation of this phenomenon is to be found in the fact that a portion of the total phosphorus contents of iron and steel—varying according to circumstances—has separated out in the form of grains of iron phosphide  $Fe_3P$  or manganese phosphide  $Mn_3P_2$ , whilst the remainder of the phosphorus is distributed more or less uniformly through the ground-mass. Whilst the latter, which is given off during the treatment with dilute acids as phosphuretted hydrogen, naturally has a powerful influence on the mechanical properties of the material, the phosphide particles distributed throughout the ground-mass, enveloped in it, and insoluble in dilute acids, are entirely, or almost entirely, without influence on the mechanical properties of the material, though they may in some circumstances be undesirable, owing to their great hardness in the subsequent treatment of the metal, as for instance in turning, &c.

Owing to the fact, already referred to, that the manganese phosphide grains  $Mn_3P_2$  contain twice as much phosphorus as the particles of iron phosphide  $Fe_3P$ , the separation of the phosphorus in the form of grains of phosphide must be facilitated by the presence of manganese, which must therefore counteract the prejudicial action of phosphorus, as it has long been known to do. Moreover, it is highly probable that the segregated grains of phosphide are the larger, and are the more readily observed during the mechanical treatment of the material; the more fluid, that is to say, the hotter the material was and the slower it

was cooled, the more time, that is, which was available for liquation.

Recently two samples of weld iron came under the author's notice, which confirm this view in the most complete manner. The investigation of these materials gave the following results :—

	A.	B.
Chemical composition :—		
Carbon . . . . .	0·110	0·123
Silicon . . . . .	0·105	0·108
Manganese . . . . .	0·097	0·094
Sulphur . . . . .	0·025	0·022
Phosphorus . . . . .	0·4423	0·4557
Tensile strength, tons per square inch . . . . .	$\left\{ \begin{array}{l} 28·06 \\ 25·71 \\ 27·11 \\ 28·13 \\ 26·03 \end{array} \right\} 27·0$	$\left\{ \begin{array}{l} 19·17 \\ 29·21 \\ 18·79 \end{array} \right\} 22·4$
Elongation, per cent. (on 50 millimetres) . . . . .	$\left\{ \begin{array}{l} 10·0 \\ 8·0 \\ 10·0 \\ 4·0 \\ 10·0 \end{array} \right\} 8·40$	12·0
Reduction of area, per cent. . . . .	$\left\{ \begin{array}{l} 37·6 \\ 11·7 \\ 31·4 \\ 28·3 \\ 37·6 \end{array} \right\} 29·32$	25·6
Remarks . . . . .	{ Welds easily. Very great cold-shortness.	Welds easily. Great cold-shortness.

As the material A showed far more cold-shortness, despite its lower percentage of phosphorus, than did B, in both, in their condition as received, the quantities of phosphorus were determined which were evolved as phosphuretted hydrogen or separated as phosphide. In order to study the changes in the phosphorus produced by hardening and annealing, the material was heated to about 1000° C., and then hardened by plunging into cold water, and also further examined after annealing at 1000° C. and then slowly cooling. The phosphorus of the phosphide was determined by treating the residue left, after treatment of the material by dilute sulphuric acid (1 to 10), with nitric acid of 1·2 specific gravity, oxidising with permanganate, dissolving the resulting

manganese dioxide precipitate with a little oxalic acid, addition of ammonium nitrate, and then precipitation by molybdate solution. The results obtained were as follows:—

Condition of Sample.	Phosphorus Contents.	A.		B.	
		Per 100 Parts of Sample.	Per 100 Parts of Phosphorus.	Per 100 Parts of Sample.	Per 100 Parts of Phosphorus.
Annealed . . . {	Evolved as PH <sub>3</sub> . . .	0·3425	77·66	...	...
	Separated as phosphide	0·0998	22·34	...	...
	Totals . . .	0·4423	100·00	...	...
As received (naturhart) {	Evolved as PH <sub>3</sub> . . .	0·3553	80·33	0·2887	63·35
	Separated as phosphide	0·0870	19·67	0·1670	36·65
	Totals . . .	0·4423	100·00	0·4557	100·00
Annealed and hardened in cold water . . . {	Evolved as PH <sub>3</sub> . . .	0·3677	83·13	0·3138	68·75
	Separated as phosphide	0·0746	16·87	0·1424	31·25
	Totals . . .	0·4423	100·00	0·4557	100·00

The above table shows that here again a high percentage of the phosphorus that is evolved as gas on solution of the material in dilute acids corresponds with increased cold-shortness; and, further, that the quantity of the separated phosphide is greater in the case of the annealed metal, but less in the hardened metal, than in the metal in its "natural hard" condition. With perfect justice, therefore, and analogous to the different modifications of carbon, it is possible to describe that form of phosphorus which escapes as H<sub>3</sub>P, and which caused cold-shortness, as the dangerous or "hardening" phosphorus, whilst the modification insoluble in dilute acids may be named the "phosphide" phosphorus.

The inter-conversion of these two forms of phosphorus takes place evidently in an identical manner to the changes in the forms of carbon modifications, only that it would appear to be less far-reaching in the case of the former, and also to take place far more slowly, than with the latter. It would further appear, as indeed has been verified by the researches of Behrens and Van Linge, that the deposition of the phosphide takes place within the carbide. From the fact that the hardening capacity

of steel is reduced by an increase in the percentage of the phosphorus it contains, it has been rightly concluded that the phosphorus favours the separation of the carbide. On the other hand, the influence exerted by the phosphorus increases with the percentage of the combined carbon, such as "hardening carbon." One might be disposed to see in this some peculiar chemical mutual action between the two elements; but it would nevertheless still be possible that the cause of this phenomenon might be largely due to purely physical causes—to an increase of the mass of the readily fusible portion of the alloy, which is the last to solidify, and to the greater inducement to crystallisation resulting from this, and differences in the solidifying points of the phosphides and carbides.

If from the last table the ratio existing between the contents of phosphide-phosphorus of the samples in their "natural hard" condition, and after hardening in water, is calculated, it will be found that in

$$\text{Sample A} = \frac{P_n}{P_h} = \frac{0.0870}{0.0746} = 1.166$$

$$\text{Sample B} = \frac{P_n}{P_h} = \frac{0.1670}{0.1424} = 1.172$$

—so similar to each other, that is, that one is misled into the assumption that the separation of the phosphide results, with varying percentages of phosphorus, in a degree proportionate to the energy of the hardening process.

In this connection former experiments of Osmond and Werth \* must be referred to, in which in a series of samples the phosphorus that can be evolved as  $\text{PH}_3$  was also determined by absorption by silver nitrate. The results of their investigations are shown in the following table, in which another column is added, showing the difference between the total phosphorus and that evolved as  $\text{PH}_3$ —that is, the quantity of "phosphide" phosphorus:—

\* *Theorie Cellulaire*, Mem. de l'Artillerie de la Marine, 1887, vol. ii. p. 273.

Material.	Analysis.					P. Evolved as $\text{PH}_3$ .	P. not Evolved as $\text{PH}_3$ = Phos- phide Phos- phorus.
	C.	Mn.	Si.	T.	P.		
	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.
<i>Acid Bessemer Steel—</i>							
Before the addition of spiegeleisen . . . }	...	...	...	...	0·065	0·044	0·021
After such addition . . .	...	...	...	...	0·065	0·028	0·037
<i>Basic Bessemer Steel—</i>							
Before the addition of spiegeleisen . . . }	...	...	...	0·038	0·046	0·030	0·016
After such addition . . .	...	...	...	0·022	0·046	0·018	0·028
<i>Open-hearth Steel—</i>							
Before the addition of spiegeleisen . . . }	...	...	...	...	0·033	0·022	0·011
After such addition . . .	0·49	0·37	0·075	0·024	0·441	0·014	0·027
Hardened . . . .	0·49	0·37	0·075	0·024	0·041	0·013	0·028
Very soft steel . . .	0·18	0·10	...	0·060	0·070	0·049	0·021
"Diamond" steel No. I.	1·17	0·18	0·44	0·018	0·033	0·005	0·028
Ordinary Bessemer steel	0·50	0·59	0·11	0·042	0·065	0·030	0·035
Ordinary Bessemer steel	0·49	0·74	0·23	0·022	0·065	0·026	0·039
Pig iron . . . .	...	...	...	...	0·055	0·041	0·014
Burnt iron from the Massele, in pseudo-crystals }	0·11	trace	0·058	0·032	0·810	0·147	0·663
Spiegeleisen . . . .	4·00	19·84	...	...	0·145	0·004	0·141
Basic Bessemer pig iron .	3·00	2·16	1·71	0·13	2·500	0·037	2·463
Forge pig iron . . .	3·00	0·07	0·37	0·48	1·750	0·038	1·712

On the whole, these results show with high percentages of carbon high percentages too of separated phosphides, which is recognisable in the case of the first six samples, which refer to three different kinds of steel before and after the addition of spiegeleisen. One exception is shown by the "diamond" steel with 1·17 per cent. of carbon, which only contained 0·028 per cent. of phosphide-phosphorus — perhaps, however, only on account of the fact that its total phosphorus contents amounted to but 0·033 per cent. The burnt iron is another exception. This might, perhaps, be due to the oxidation of the hardening carbon, or to the fact that the conversion of the "hardening" phosphorus into phosphide takes place at a somewhat high temperature, and but very slowly.

If, therefore, phosphorus appears to favour the separation of carbide, it would seem that, conversely, carbon favours the separation of phosphide. Consequently the phenomenon of

cold-shortness is not to such a very large extent, or at least not solely, dependent upon the quantity of hardening phosphorus present. There has at least to be taken into consideration the joint quantity of the carbides and phosphides present, or, in other words, the quantity of the portion that is the last to solidify in the cooling down of a molten metal, inasmuch as with an increasing quantity of the mother metal the formation of crystals in the portion of the iron that is the first to solidify is obviously facilitated.

It may be well to examine more closely at this point what it is that happens when molten iron solidifies, and for this purpose to consider what occurs during the solidification of salt solutions.

Most aqueous salt solutions, as well also as mixtures of solid bodies in a fluid state, remain fluid at temperatures far below the melting points of the dissolved salts, and all can be cooled down without solidification to less than 0° C., that is to say, below the melting point of their most fusible constituent, provided the degree of concentration is not too great. On cooling *concentrated* solutions a point is first reached at which salt is deposited, as, in general, the solubility diminishes with the temperature. This point is to be considered as the solidifying point of the salt in the presence of water.

In certain conditions molten pig iron is a saturated solution of carbon in iron. On cooling this, the excess of the carbon present must separate out, and in a *crystalline* form—as graphite, that is. Ferrochrome, high in chromium, is to be viewed as a solution of chromium in iron. If this cools down below a certain temperature, the chromium begins to separate out in a crystalline form, not as such, however, but combined with iron and carbon in a manner quite analogous to those salts which crystallise with water of crystallisation from their aqueous solutions. Such chromium crystals were found in about 50 per cent. ferrochrome by Behrens and Van Linge,\* and by the author,† who examined them and found them to have a composition corresponding to the formula  $\text{Cr}_3\text{FeC}_2$ .

As has been observed above, the degree of solubility increases in general with the temperature. From a solution saturated at

\* *Zeitschrift für Analytische Chemie*, vol. xxxiii. p. 513.

† *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, 1896, p. 14.

a high temperature, a portion of the dissolved salt will crystallise out even at a fairly high temperature, and usually together with a portion of the solvent—with water of crystallisation. This occurrence corresponds exactly with the separation of the ferro-chrome carbide from 50 per cent. ferrochrome to which reference has just been made.

If the solution is less concentrated than that corresponding to the temperature at which the salt first mentioned begins to separate out, with or without water of crystallisation, a further diminution of temperature is necessary until the salt begins to crystallise out, which it then does with another and usually higher proportion of water of crystallisation. Thus, for instance, a solution of manganous sulphate yields—

At about 100° C., crystals of . . . . .	MnSO <sub>4</sub> +8H <sub>2</sub> O
Between 6° and 20°, crystals of . . . . .	MnSO <sub>4</sub> +6H <sub>2</sub> O
Below 6°, crystals of . . . . .	MnSO <sub>4</sub> +7H <sub>2</sub> O

It is identically the same in the case of iron alloys. Ferro-chrome containing 50 per cent. of chromium, contains, as has already been observed, crystals of Cr<sub>3</sub>FeC<sub>2</sub>; whilst the alloy with 13 per cent. of chromium and less, contains, on the other hand, crystals of Cr<sub>2</sub>Fe<sub>7</sub>C<sub>3</sub>.\* As will be seen, the product separated from the more dilute solution, the separation of which must have occurred at a lower temperature, contains far more of the solvent, iron containing carbon, analogous to the water of crystallisation, than did the compound which separated from the more concentrated solution.

On the other hand, on cooling down *dilute* solutions a portion of the water of the solution first freezes, and the remaining liquid portion consequently becomes more concentrated. The freezing point of aqueous solutions is, however, the lower the greater was the degree of concentration. On further cooling, therefore, more and more ice forms, and the percentage of salt in the solution increases, until at its freezing point it is also quite saturated. Then salt and ice *solidify together* at a constant temperature, as the composition undergoes no further change.

It is quite the same as this when ingot iron and ingot steel solidify, as this too represents in most cases dilute solutions. The cooling and solidification of iron relatively poor in foreign

\* Behrens and Van Linge, *loc. cit.*

constituents begins first at the sides and at the bottom of the moulds, by which the portion of the metal remaining liquid, and enriched too in foreign constituents, is forced towards the interior of the casting. On further cooling, another inside layer solidifies, richer in foreign elements, and the still more concentrated liquid portion is driven further towards the centre, and so on. As, however, the iron does not solidify suddenly, but in its passage from the fluid to the solid state passes through a thick-fluid pasty stage, the portion of the metal remaining liquid can never be completely driven towards the interior of the mass, but isolated drops must remain enclosed in the thick fluid magma, and solidify in this position subsequently. This must be especially the case in the portion nearest the sides, which solidify the most rapidly, and is the cause of the formation of the so-called *Randstahl* (at the sides of the casting).

If the process of cooling and solidification proceeded in this manner until complete, the result would be a substance of approximately the same composition at the sides and at the bottom, whose contents of accompanying constituents would constantly increase towards the centre, and within a certain degree towards the top. The effect, however, of the molten centre of the casting is to cause a portion of the already cooled and solidified exterior, especially above the centre of the bottom part, to be reheated and brought to a pasty, or even perhaps partly to a fluid state. The drops of metal rich in foreign elements which were originally included in this pasty mass, find time and opportunity to separate from this under the pressure of the superimposed column of molten metal, and possibly, too, assisted by variations in specific gravity. The result of this process must be a further enrichment of the upper central cylinder, and an impoverishment in accompanying constituents of the bottom portions as compared with the centre.

As, however, even after complete solidification, separations, as of carbide for instance, take place in the mass of the iron, and solution phenomena when the metal is reheated, the solidified iron mass must be looked upon as a solution in a solidified state. The carbide and phosphide separations which make themselves noticeable in this, are, however, taken on the whole, by no means to be considered as substances which have crystallised out, but

as the last remainder of the last portion of the mother metal to solidify, as mentioned above. We should therefore look upon the course of events in the cooling down of a mass of molten iron relatively poor in foreign matter in the following way:— In the first place, pure iron, the solvent, solidifies at the sides where the solidification first commences and is most rapid, forming a solid crust (*Randstahl*), which takes up as enclosures larger or smaller quantities of the mother liquid. On further cooling, more pure iron continues to solidify, the particles of which swim about in the still fluid residue of the iron rich in impurities, which is now surrounded by the crust. As these solid granules of iron continue to increase from outside towards the centre, the mass of metal becomes more and more thick fluid. Finally the mother metal solidifies, which up to this had remained fluid, filling up all the space between the granules. Since, however, the cooling ensues from the outside inwards, and as consequently also the increase in size of the crust of pure iron must take place in the same way, it cannot otherwise happen but that the spaces between the granules, filled with the mother metal, are smallest immediately below the crust, and become wider and wider towards the interior, and consequently an accumulation of the mother liquid must take place towards the centre.

If the degree of cooling has reached a certain limit, the mother liquid solidifies also. But this does not end the process, for by further cooling there separates from this solidified solution, if it is still a question of dilute solutions, either the "solvent" once again, though it is true it is now solidified, or, if these "solid" solutions are to be considered as concentrated, the dissolved material, carbide, phosphide, &c.

It follows from the above that all the substances occurring with the iron must exist in this in at least two different forms. This has, as a matter of fact, already been proved in the case of many of these. In addition to carbon and phosphorus, sulphur occurs in iron in two forms, chromium in three, and manganese, tungsten, &c., in several different forms. Chief of these are the following:—

I. *Dissolved substances separated out from concentrated solutions.*  
—Graphite, ferrochrome, carbide, &c., which are always characterised by a more or less well-defined crystalline form.

II. *The solvent separated out from dilute solutions.*—As the chief example of this, pure granular iron can be taken. Such separations are always, it is true, crystalline, but less definitely than the above.

III. *Solidified mother metal.*—In which, again, secondary separations can be distinguished, taking place only in the solid material.

If, as is not improbable,  $\text{Fe}_3\text{P}$  and  $\text{Mn}_3\text{P}_2$  possess higher melting points than the last remainders of the still fluid mother metal, and are relatively little soluble in this, the process of solidification in its final stages can again change round. That is to say, it is not impossible that these last still fluid remainders of the mother metal may, at the temperature here in question, again be considered as saturated solutions of phosphorus, and that at this stage of the cooling the phosphorus, or rather the phosphides, may again separate, together with a portion of the solvent, as a kind of water of crystallisation, iron and carbon, which then evidently occurs as carbide. As, however, the still remaining residue of the mother metal certainly solidifies not very much below the temperature at which the phosphides separate out—soon after this, that is—the phosphides have not time enough in which to form definite crystals. It would best be seen from this way of looking at the process of solidification, that phosphorus favours the separation of carbide, and diminishes the capacity for hardening of the iron, in that not only is carbide separated simultaneously with the phosphide, but that, like salt-crystals in supersaturated solutions, these secretions favour the further separation of the carbide.

*CORRESPONDENCE.*

Mr. C. H. RIDSDALE, of the North-Eastern Steel Company Limited, stated that Baron Hanns Jüptner von Jonstorff had given the members a valuable paper and drawn a most interesting analogy between "hardening" and "carbide," carbon and "hardening," and "phosphide" phosphorus, and had rendered great service by discriminating between really injurious phosphorus intimately combined with the steel, and relatively harmless phosphorus separated out from the ground mass and thus simply intermixed. This was very important, for, as he pointed out, phosphorus separated in grains as phosphide was "almost entirely without influence on the mechanical properties of the material"—a conclusion which his (Mr. Ridsdale's) experience fully confirmed; and as samples high in phosphorus were generally so on account of segregation, the excess of phosphorus so present was almost invariably in that relatively harmless form, and to some extent as phosphate. As regarded the author's remarks, with reference to Professor Cheever on the existence of phosphorus as phosphate, this undoubtedly was met with under certain conditions, although in normal steel it was only present to a very small extent, say, under one hundredth per cent., but where segregation had occurred it might be found in very much larger quantities. He (Mr. Ridsdale) had frequently examined samples by a method similar to that quoted, viz., dissolving in dilute acids, with precautions to preclude the possibility of oxidation of phosphorus to phosphoric acid whilst so dissolving, and he had estimated the phosphorus left undissolved, and the phosphorus existing as phosphoric acid which was found in the solution after filtering off the residue, the phosphorus evolved as phosphoretted hydrogen being taken by difference.

He did not see any mention in the paper of the solution (which would contain any phosphorus existing as phosphate) having been examined. It was quite reasonable to expect to find some phosphorus as phosphate, as the reaction between the

remaining traces of oxides with which the steel was charged at the end of the blow and the re-carburiser went on to a slight extent so long as the steel remained liquid, and the oxides of iron or manganese present reacted upon the phosphorus, forming phosphoric acid, which combined with oxide of iron or manganese. In proof of this he stated that, about ten years ago, whilst following up the subject, and testing a series of samples from the lower to the upper part of the ingot, he was able to pick out from a billet crop from the top part of the ingot, slag which, on analysing, was of the following composition :—

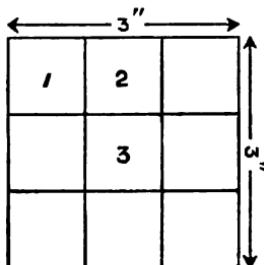
	Per Cent.
Manganese oxide . . . . .	. 74·50
Ferro oxide . . . . .	. 7·71
Ferric oxide . . . . .	. 7·70
Alumina . . . . .	. trace
Lime . . . . .	. 0·80
Magnesia . . . . .	. 0·75
Silica . . . . .	. 6·70
Sulphur . . . . .	. 1·07
Phosphoric acid . . . . .	. 1·06 = { 0·46 p. o. .      phos.
	<hr/> 100·29
Less oxygen of bases replaced by sulphur . . . . .	. 0·53
	<hr/> 99·76

The constitution of the slag may be—

	Per Cent.
Silicate of manganese . . . . .	. 16·56
Silicate of iron . . . . .	. 6·03
Magnetic oxide of iron . . . . .	. 11·16
Manganese oxide . . . . .	. 62·86
Lime, magnesia, phosphoric acid, &c. . . . .	. 3·87

In the same series of experiments, in order to determine the vital point, viz., the effect of such segregated phosphorus (whether as phosphates or phosphide) upon the mechanical properties of the steel, from a number of 3-inch billet crops from the top portion of the ingot, which would show the most segregation, some were selected which showed this in most marked degree, and were cut up longitudinally, so that their cross section was transversely divided into nine pieces somewhat under 1-inch area each, and analyses, tensile, and bending tests made of No. 1, the corner; No. 2, the centre of the outside; and No. 3, the core.

The average phosphorus in the corner (No. 1) was 0·07 per cent., in the middle portion of the side (No. 2) 0·06 per cent., and in the central core (No. 3) 0·10 per cent. The manganese and carbon were also slightly higher in the centre core (No. 3). The average tensile strain of Nos. 1 and 2 was the same, viz., about 29 tons, but that of No. 3 was in every case lower, averaging 2 tons less, or 27 tons. Thinking this reduction in tensile strength might possibly be due to the less area of actual steel, there being this segregated slaggy matter interposed between the



fibres, and to make sure that the steel itself was not harder in the core than the outside portions, the pieces were subjected to bending tests. The cores, No. 3, all stood bending quite close double, whilst Nos. 1 and 2 outside pieces broke off after bending through various angles from 30° to about 110°, thus clearly showing the mechanically soft condition of the core, which, judged by analysis, should be very much harder, as it was much higher in phosphorus. This also bore out the separation of phosphide, favouring the separation of carbide, as stated in the paper.

Mr. JOHN PARRY stated that, as the author had said, there could be little doubt that the influence of phosphorus on iron varied considerably, and in accordance with the conditions summarised. That might be said of carbon, for the latter in his opinion was even more energetic in its action than phosphorus; in other words, setting aside for the moment the relative merits of a carbon or phosphorus steel, a true or pure carbon steel was more sensitive to external influences than iron containing severally either phosphorus, sulphur, &c., proportionally in excess of the carbon, which practically was always a constituent of iron.

Those engaged in the manufacture had long ago known from general experience that the addition of a fixed known quantity of a foreign element to iron did not invariably give similar finished metal. It was within his own experience, which he was confident could be confirmed by that of others, that the analyses of a semi-fused metal—such, for instance, as soft puddled bar, semi-hard steel, or even hard steel, all of which could be severally manufactured in the puddling-furnace by suitable treatment—were not applicable in the case of metal fused at high temperatures, such as steel or ingot iron.

They must, however, frankly confess that they did not appear to have had any clear ideas, or to have given a definite explanation of the phenomena observed, although general statements had from time to time been put forward, very nearly approximating to the truth. Amongst these he might be pardoned for re-stating that some discrepancies might be due to the state, if he might so term it, in which the mother-steel existed. According to Graham, an element may be either in the colloid or crystalline form, and it is probable that iron in mass may be a mixture of these, the relative proportions varying with the method of treatment. Granting this, it did not seem probable that it could be assumed that the addition of a fixed quantity of some foreign element to iron would always give like results. The author's lucid summary of the causes of the discrepancies, viz., cold-short varieties, such as burnt iron, &c., inclination of steel to crystallise, &c., seemed, however, to afford us a clearer explanation of much that, if not quite new, was yet only dimly inferred, and which indeed, strictly speaking, could only be termed empirical knowledge, based on the experience gained in ordinary working.

He (Mr. Parry) had long thought that their ordinary analytical methods of procedure as applied to the examination of iron and steel and deductions therefrom needed extension and elaboration. He was pleased, therefore, to note that Baron Jüptner had, in common with others, extended their methods of research. There could be little doubt that metallurgical chemists would shortly be enabled to afford valuable information far more trustworthy and useful than that afforded by their present crude analysis. It went without saying that just now, by the combined efforts of the chemist and metallographist, they had acquired informa-

tion on the chemical properties of steel which almost amounted to a revelation, and it seemed that there was yet more to come in the future. The explanation of the phenomena observed in the course of the experimental results quoted seemed very complete. Based as it was on the recognised fact that molten iron containing foreign matter was strictly comparable with water containing salts in solution, it seemed most convincing, and, he thought, must meet with general acceptance. Molten iron certainly had a solvent action on certain elements. By slow cooling a portion only was retained in solution ; it followed, therefore, that these elements should be classified in order of solution, and their influence studied. Some, as was already known, were more energetic, and had a more marked effect on the quality of iron than others. More especially this applied to carbon, which appeared to be not easily soluble in iron, and consequently easily precipitated, whilst the precipitation of other bodies seemed problematic, or at any rate required further investigation.

There was possibly scope for discussion in detail on some minor points in the papers before them, yet he was fain to accept the author's conclusions as affording a rational explanation of the behaviour of phosphoric steel under varied conditions, as also, generally speaking, for the other elements.

In cases of simple solution the dissolved substance might be regarded as being evenly distributed throughout the solvent. The substance was dissolved by virtue of osmotic pressure, osmotic being the equivalent for gaseous pressure, which pressure increased for constant volume proportionally to the absolute temperature.

Accepting the physical or gaseous theory of solution, developed by Van't Hoff in 1886, who proved that osmotic pressure was really a force of considerable power, "the physical theory of solution," founded on the identity of osmotic with gaseous pressure, seemed more capable of affording a satisfactory explanation of the facility with which other elements were distributed or conventionally dissolved in iron or as gold distributes itself throughout the mass (Professor Roberts-Austen), than the old or chemical theory of solution. There could be no difficulty in conceiving that osmotic pressure was an actual force in the case of a mass of matter conventionally termed a solid. The quantity interpenetrating (dissolved) in a given time was simply

a function of the temperature applied. At low temperatures the effective osmotic pressure in the solids was comparable to that of a liquid evaporating under pressure of its own vapour; evaporation (in that case synonymous with interpenetration, diffusion, solution, the first being the most appropriate term) was correspondingly retarded.

The theory of solution might admit of extension in the following way:—It appeared as the outcome of recent researches that chemical action, or something closely approximate, took place between solids even at low temperatures. It was also well known that it was difficult to draw the line between absolute solution and matter finely suspended in a liquid; also that gases, liquids, and solids could not be absolutely differentiated. Messrs. Harold Picton and E. F. Linder said, indeed, that there was a continuous series of grades of solutions passing without break from suspension to a crystallised solution.\* They must not forget Professor Roberts-Austen's recent remarkable demonstration of the diffusion of gold and other solid metals into each other. It was known that even a refractory, comparatively infusible element like iron might be vaporised, and that even at low temperatures no element could be said to be perfectly stable.

It was even probable that such infusible substances as carbon or iron might slowly undergo dissociation at ordinary temperatures, very much as water evaporated when freely exposed in space. The quantity of matter thus presumably vaporised must be inappreciable, yet it afforded a probable explanation of the diffusion of solids into each other. It was evident that any mass or mixed masses of matter existed in an atmosphere formed by themselves; strictly speaking, the sensible particles or (query) molecular groups comprising the mass were not completely isolated from each other, and therefore the conception of the interpenetration of iron by phosphorus carbon, or indeed any other element, was thus, he thought, rendered more easy.

Mr. F. OSMOND agreed, on the whole, with the author's views of cold-shortness. As an outcome of his own researches on the condition of the phosphorus, which were made in conjunc-

\* *Transactions of the Chemical Society*, January 1891.

tion with Mr. Werth, and which had been so kindly referred to by the author, he thought he had found a means of determining qualitatively, and perhaps quantitatively, the cold-shortness of iron and steel. On maturer consideration, however, he had concluded that the relation between the two factors in question, although it certainly existed, was really indirect, because the presence of carbon and manganese, on the one hand, and the calorific treatment, on the other hand, interfered with the results and disturbed their regularity. Certainly the question was exceedingly complicated, as were all those relative to iron, but it had been ably stated in the latter pages of the paper. The comparison between iron and steel and liquid solutions was absolutely justified. In that connection reference might be made to an experiment by Mr. Lencauchez. On heating phosphoric pig iron to a bright red in a reducing atmosphere, a large number of molten globules were exuded, and these were much richer in phosphorus than the original metal. With alloys of iron, however, the solidifying point was not the last phenomenon that had to be studied. The allotropic transformations of solid iron played the same part as the solidification of liquid iron, and induced, for each element or compound present, a change either in the solubility or in the composition; the metal might, indeed, be said to pass during cooling from the liquid state through three successive solidifications.

Mr. J. E. STEAD, Member of Council, said that many years ago he had followed to a certain extent a series of experiments on the same lines as the author, and was convinced at the time that the relation between the phosphorus evolved in the gaseous form and that retained in the insoluble varied in different samples, but he had not had an opportunity of correlating the results with the mechanical properties; hence his work was of little value, excepting that it coincided with that given by the author. That gentleman had followed the matter up, and the results he gave must lead them in the future, especially in the great steel-producing manufactures, to follow up the research elaborated in the paper, and he (Mr. Stead) suggested that the managers of all such steelworks should hand that paper to their

analysts with instructions to do so. He said there could be no doubt that phosphorus was very variable in its effect, but hitherto the difference had been believed to be caused by the more or less coarsely granular structure which phosphoric material could be made to assume by differences in heat treatment, and in the work applied in rolling or hammering. It was certain that that had a very important bearing upon the strength of the material. By a great amount of work upon phosphoric material it was made into a condition capable of considerably greater elongation than the same material not so treated; but for all that, in all probability the condition in which the phosphorus existed might have as important an effect upon the mechanical properties. Much work would have to be done in the direction mapped out before it could be demonstrated beyond all doubt that this was the case.

## ON THE DETERMINATION OF HARDENING CARBON AND CARBIDE CARBON.

BY THE BARON HANNS JÜPTNER VON JONSTORFF.

IT is hardly necessary to point out the importance, both from scientific and practical points of view, of having methods available for rapidly and simply quantitatively determining the various forms of carbon. As, however, methods of this kind have unfortunately hitherto been wanting, the author has endeavoured to supply the deficiency, and decided, after various researches in other directions, to investigate whether the colorimetric method originally introduced by Eggertz would, if modified, be adapted for the determination of the different forms of "combined" carbon.

In recording in this paper the results of this investigation, the author cannot refrain from pointing out that in colorimetric determinations absolute accuracy can obviously not be expected. In the comparison of colour intensities an error of  $\pm 5$  per cent. must be reckoned with, and moreover, with the small quantities which are used in practice, and with the various kinds of operations, other sources of error are introduced. Nevertheless, the results obtained may be regarded as perfectly adequate for practical purposes, and it is to be hoped that the International Commission on the Analysis of Iron and Steel, on the scope and design of which the author had the honour to report at the last spring meeting, will, in revising the methods described in this paper, render them more nearly perfect—a task for which the author in his present position has no spare time.

In the first place, it may not be out of place to give a short review of our present knowledge of the subject. As is well known, there are now distinguished in iron and steel at least four different forms of carbon, which have the following characteristics :—

a. *Hardening Carbon.*—On dissolving in dilute hydrochloric or sulphuric acid this is given off as strongly smelling carburetted

hydrogen gas. On dissolving in cold nitric acid of 1·2 specific gravity it forms at first a dense black residue,\* which dissolves very rapidly on shaking or at rest in a few minutes, without noticeable evolution of gas, and on heating the solution to 100° C. is gradually given off in the form of gas, the solution coloured dark by the dissolved carbon compounds becoming increasingly lighter in colour.

*β. Ordinary Carbide Carbon.*—On heating with strong acids this modification is given off in the form of carburetted hydrogen. If the sample of metal is dissolved in very dilute hydrochloric or nitric acid at ordinary temperature, a grey or brown mass (carbide) is left, which, according to Müller,† consists of a number of silvery granules which when dried catch fire at a comparatively low temperature. According to F. Mylius, F. Förster, and G. Schoene,‡ this carbide is decomposed even by the most dilute acids, and in a wet condition is oxidised by the oxygen of the air. On dissolving the sample of iron in cold dilute nitric acid of 1·2 specific gravity, it remains as a flocculent brown mass, which on heating gradually dissolves without evolution of gas, and imparts to the solution a brown colour which changes but little, even on boiling.§

*γ. Graphitic temper-carbon* is neither soluble even in boiling acids nor volatilised. It remains in the residue as almost pure carbon. It is black, without lustre, and perfectly amorphous, and can, by ignition under oxidising influences, be entirely removed from iron, according to Forquignon,|| even by igniting in a current of dry hydrogen, in this case of course as carburetted hydrogen.

*δ. Graphite* behaves towards acids in the same way as temper-carbon, from which it is distinguished only by the crystallisation. It is usually assumed that graphite is not acted upon by boiling nitric acid. This is however incorrect, as it is oxidised slowly but completely, a reaction which I have utilised for many years

\* Osmond and Werth, "Théorie Cellulaire des Propriétés de l'Acier," *Annales des Mines*, 8th series, vol. viii. pp. 5-84.

† *Stahl und Eisen*, 1888, p. 292.

‡ *Zeitschrift für anorganische Chemie*, 1896, vol. xiii. p. 38.

§ Osmond and Werth, *loc. cit.*

|| "Recherches sur la Fonte Malleable," *Annales de Chimie*, 5th series, vol. xxiii. p. 443.

past in the determination by the chlorate method of manganese in grey pig iron. Temper-carbon behaves in a similar manner.\*

The methods hitherto employed for the quantitative determination of the various forms of carbon are briefly as follows:—

1. Temper-carbon and graphite, which cannot as yet chemically be separated, are best obtained by dissolving the sample in nitric acid, collecting on a filter, and determining in the usual manner.

2. The difference between the total carbon and the proportion of graphite and temper-carbon found, according to 1, gives the so-called "combined carbon," which may, however, also be determined colorimetrically by the methods of Eggertz and Stead. These methods present the disadvantage that they are perfectly trustworthy only when the different modifications of combined carbon in the sample and in the normal steel are in similar proportions.

3. The separation of the carbide carbon from the iron is based† on its insolubility in dilute cold acids; it is deposited in the form of a greyish black powder. Pure iron, on the other hand, and iron uniformly alloyed with a little carbon, is dissolved to a clear solution, the carbon being evolved in the form of carburated hydrogen. Whilst Müller‡ employed dilute sulphuric acid, Sir Frederick Abel and Deering used a mixture containing in one litre 100 grammes of potassium bichromate and 90 grammes of sulphuric acid. The method introduced by F. C. G. Müller is as follows: For every gramme of the sample, comminuted as much as possible, 20 cubic centimetres of 10 per cent. sulphuric acid is added, and the beaker containing the mixture is placed under a bell-jar, through which a quite slow current of illuminating gas is allowed to flow. In a few days' time the action of the acid is complete. The residue is filtered off on to a weighed filter, washed with a large quantity of boiling water, and finally with a mixture of ether and alcohol. The filter and its contents are then placed in a weighing bottle in an air bath at 120° C., care being taken to pass illuminating gas slowly through it by means of a cork with two holes bored in it. After drying it is allowed to thoroughly cool in the current of gas. The substance is so

\* The occurrence of diamond need not be considered in this paper.

† A. Ledebur, *Stahl und Eisen*, 1888, p. 743.

‡ *Loc. cit.*

inflammable that it always ignites spontaneously if the glass is even just warm. When it is merely a question of determining the carbide carbon and not of isolating the carbide itself, the course of procedure is to filter over asbestos instead of through a paper filter, wash free from iron with water, then with ether and alcohol (which according to Ledebur may be dispensed with), finally with water again, and determine the separated carbon by one of the known methods as carbonic anhydride. Mylius, Förster, and Schoene\* found that the carbide is least attacked by dilute acetic acid. The solution of the iron in this acid occupies, however, much too long a time for it to be of practical use.

4. Hardening carbon has not hitherto been determined directly. It is obtained by subtracting from the proportion of total carbon those of the other forms of carbon. In this way all the errors occurring in the other determinations are accumulated, so that the result is by no means free from error.

Consequently it is undoubtedly a considerable advantage that the new methods enable the hardening carbon to be determined directly.

As the methods to be described for the determination of the hardening and carbide carbon are colorimetric, reference must here be made to some interesting investigations of such methods.

Osmond and Werth† have made very exhaustive researches regarding the accuracy of the Eggertz method of determining carbon which are of special importance for the purpose of this paper. A comparison of the Eggertz and the Bousignault methods gave the following results:—

Description.	Eggertz, Carbon.	Bousignault, Carbon.
	Per Cent.	Per Cent.
Steel, ordinary . . . . .	0·500	0·492
Steel, hardened . . . . .	0·325	0·520
Steel, first hardened, then rapidly heated in the smith's fire and cooled in the ashes . . . . .	0·480	0·537
Steel, forged . . . . .	0·520	...

\* Loc. cit.

† "Théorie Cellulaire des Propriétés de l'Acier," Mémoire de l'Artillerie de la Marine, 1887, p. 220.

As hardened steel is soluble in nitric acid without leaving a carbonaceous residue, and as dissolving in nitric acid imparts to this a paler coloration than is the case when annealed steel is dissolved, although the same colour results in both cases, the authors instituted an investigation to ascertain whether the lack of carbon, which is shown in the case of hardened steel by the Eggertz sample as compared with that of Bousignault, had not escaped in a gaseous form during the solution.

On carefully watching what happens when one and the same steel in its commercial and hardened form is attacked by nitric acid of 24° B., using 25 cubic centimetres to 5 grammes, the following will be observed: The small dissolving flasks, to avoid increase in temperature, were placed in a water bath, having a temperature of 15° C. The iron dissolves at first in five or six minutes with a violent ebullition of gas. At this moment the two solutions are almost colourless. *Hardened* steel leaves at the bottom of the vessel a deep black substance, which dissolves almost instantaneously if it is allowed to stand quietly. The solution results without any evolution of gas, and its colour is then dark brown. There remains finally a slight precipitate, brown in colour, and gelatinous, which in the cold only passes into solution with extreme difficulty. The steel in its commercial (*naturhart*) condition, neither hardened nor annealed, shows only a slight black residue at the bottom of the flask, after the iron has been dissolved away. In other respects it is identical with that resulting in the case of hardened steel, it dissolves with extreme rapidity, and imparts to the solution a somewhat slight coloration. On the other hand, numerous dark brown flocculent particles float about in the solution, which gradually pass into a gelatinous light brownish coloured mass, and resemble those resulting from hardened steel, excepting that they are far more voluminous.

On filtering off these flocculent particles, immediately after the solution of the hardening carbon, they were found to contain, when dried at 100° C. :—

Carbon.	Water.	Iron.	Oxygen+Nitrogen.	Total.
44.59	22.50	8.05	24.86	100.00

They become transparent and gelatinous when they lose their iron.

If these precipitates are filtered in the cold, and treated with a fresh quantity of 25 cubic centimetres of nitric acid, they both dissolve without any marked evolution of gas, but they impart to the brown solution a different coloration. The intensity of the colour appears to be connected with the volume of the precipitate acted upon.

If the first brown solutions, which were separated from the insoluble residues by filtration, be heated to 100° C., both of them evolve gas and decolorise, but the solution of the hardened steel decolorises relatively to a greater extent than does that of the steel in its commercially "hard" form, the evolution of gas being in this case more violent, and in the others more abundant.

If the dissolving vessels, instead of being dipped in cold water, are heated directly to 100° C., the same results ensue, and in the same order, only more quickly.

The following figures, taken quite at random from a number of others, will help to render these points more definite. Steel containing 0·85 per cent. of carbon was employed. If the coloured solutions resulting by filtration from the insoluble residue immediately after the solution of the metallic iron and hardening carbon in the *cold* are called  $L_1$ , and those obtained by repeatedly heating the residue to 100°\* be called  $L_2$ , after diluting to 50 cubic centimetres and comparing with standard steel the apparent percentage of carbon in the steel was found to be as follows:—

	Commercially Hard.	Hardened.†
$L_1$ , heated for two minutes to 100° C.	0·56 } 1·12	0·91 } 1·17
$L_2$ , heated for twenty minutes to 100° C.	0·56 }	0·26 }

A further comparison of the solutions  $L_1$  and  $L_2$ , after heating to 100° C. for forty-five minutes and for one hour and forty-five minutes, gave the following results:—

\* If the treatment be effected at a temperature of 14° C. and with acid of 12° B., or at 0° C. and with normal acid of 24° B., the solution  $L_2$  becomes greenish in colour.

† The hardened examples had been flattened out to a sheet of 1 millimetre thickness, as very irregular results were obtained from the inner portions of thicker pieces.

Description.	Apparent Percentage of Carbon.	
	Commercially Hard.	Hardened.
After forty-five minutes :—		
L <sub>1</sub> , strong evolution of gas . . . . .	0·28	0·39
L <sub>2</sub> , no evolution of gas . . . . .	0·50	0·24
	{ 0·78	{ 0·63
After one hour forty-five minutes :—		
L <sub>1</sub> , slight evolution of gas . . . . .	0·24	0·30
L <sub>2</sub> , no evolution of gas . . . . .	0·15	0·18
	{ 0·69	{ 0·48

With normal conditions, the Eggertz test shows 0·81 per cent. and 0·41 per cent. respectively in the two cases.

Immediately, therefore, after the complete action on the steel, the commercially hard and the hardened steels gave similar colorations. The subsequent heating of L<sub>1</sub> causes the differences, solution L<sub>2</sub> decolorising regularly and only slowly.

Osmond and Werth further showed that the decolorisation of L<sub>1</sub> is in direct connection with the evolution of gaseous carbon compounds. From numerous experiments made with the steel containing 0·85 per cent. of carbon, they obtained the following average results :—

Description.	Commercially Hard Steel.		Hardened Steel.
	Per Cent.	Per Cent.	
Carbon evolved as gas . . . . .	0·342		0·500
Carbon passing into solution by difference . . . . .	0·508		0·350
Totals . . . . .	0·850		0·850
The coloration of the solution corresponded to . . . . .	0·772		0·480

It would appear, therefore, that the intensity of colour of the solution is proportional to the quantity of carbon it actually contains.

If K be the coefficient by which the carbon contents found must be multiplied in order to obtain the true percentage of the dissolved carbon, there is obtained—

$$\begin{aligned} \text{For commercially hard steel} & . . . . . & 0\cdot772K = 0\cdot508 \\ \text{For hardened steel} & . . . . . & 0\cdot480K = 0\cdot350 \end{aligned}$$

from which the values 0·658 and 0·729 may be deduced for K, or on the average 0·694, thus showing a satisfactory agreement.

With a view to render the Eggertz test of use also in the case of low-carbon contents, J. E. Stead\* dissolves iron or steel filings in 12 cubic centimetres of nitric acid of 1·2 specific gravity at a temperature of 90° or 100° C., about ten minutes being necessary for this operation. He then adds 30 cubic centimetres of hot water and 13 of a solution of caustic soda of 1·27 specific gravity, shakes, dilutes to 60 cubic centimetres, mixes again thoroughly, allows to stand for ten minutes in a warm place, filters, and compares the tint with that obtained from a standard steel similarly treated. Even though the heating be continued for three or four times as long as is necessary to dissolve the metal, this does not greatly affect the results, but the solution of the carbon appears to be effected somewhat more slowly than that of the iron. An excess of acid, up to 6 cubic centimetres, does not cause any important difference, but a larger quantity causes the results obtained to be too low. The quantity of the caustic soda solution used must not be less than 13 cubic centimetres, as otherwise the carbon percentages found will be too low. Should the nitric acid used contain hydrochloric acid, a similar result ensues. The method depends on the facts that by the addition of caustic soda there is thrown out of the solution the iron oxide, which would otherwise interfere owing to its colouring power, and that the alkaline solutions of the colouring carbon compounds are far deeper tinted than are the nitric acid solutions. The application of this very promising method to the determination of hardening and carbide carbon was deferred pending other experiments.

The following experiments are based on four samples of steel, kindly supplied by Professor A. Ledebur, of Freiberg. Their composition is as follows:—

Description.	A.	B.	C.	D.
	Per Cent.	Per Cent.	Per Cent.	Per Cent.
Temper carbon . . . . .	...	0·17	...	...
Carbide carbon . . . . .	0·64	0·90	0·71	0·38
Hardening carbon . . . . .	0·14	0·18	0·22	0·55
Total carbon . . . . .	0·78	1·20	0·93	0·98
Silicon . . . . .	0·37	0·79	0·11	0·11
Manganese . . . . .	0·26	0·40	0·11	0·11
Phosphorus . . . . .	0·01	0·07	0·03	...

\* *Journal of the Iron and Steel Institute*, 1883, No. I. p. 218.

In sample B it will be seen that the carbide carbon and the hardening carbon together amount to 1·03 per cent.

In addition, other samples of steel were used whose total carbon contents had been carefully determined.

(a.) *Determination of the Hardening Carbon by Solution in Dilute Nitric Acid in the Cold.*—Usually 0·2 gramme of the sample was weighed out, and on this 10 cubic centimetres of nitric acid was poured, the sample being placed in a vessel containing cold water and dissolved, shaking frequently. The nitric acid used consisted of two parts by volume of concentrated acid and three of water. It was then filtered through a dry filter, hardened with nitric acid, 2 cubic centimetres of the filtrate transferred to a comparing tube, and diluted until it was of the same colour as the solution of the standard steel. In these tests those samples of steel containing but little hardening carbon—under 0·15 per cent.—showed a distinct greenish coloration, with a result that the colour comparison was difficult to effect. The greenish colour tint causes the solutions to appear far lighter in colour than should correspond to the carbon percentage. Numerous experiments showed, however, that the results are satisfactorily in accord if the value of the hardening carbon of the normal solution as determined for brownish-coloured solutions was multiplied by 1·3 for solutions of a greenish tint. In this way, for instance, the following values were obtained :—

No.	Sample.	1 Cubic Centimetre. Solution Corresponding with Hardening Carbon. Milligrams.	Weighed out. Grms.	Volume of Comparative Solution. Cubic Centimetres.	Hardening Carbon. Milligrammes.			Hardening Carbon. Per Cent.			Difference.
					Colorimetrically.	Gravimetrically.	Difference.	Colorimetrically.	Gravimetrically.		
1	A	0.012	0.2	4.7	0.056	0.056	0.000	0.14	0.14	0.00	
2	"	"	"	4.7	0.056	"	0.000	0.14	0.14	0.00	
3	"	0.0175	"	3.0	0.053	"	-0.003	0.135	0.14	-0.005	
4	"	0.021	"	2.5	0.063	"	-0.008	0.135	0.14	-0.005	
5	"	0.020	0.2918	4.2	0.084	0.081	+0.003	0.143	0.14	+0.003	
6	"	0.021	0.2	2.6	0.065	0.056	-0.001	0.138	0.14	-0.002	
7	"	"	"	2.6	0.065	"	-0.001	0.138	0.14	-0.002	
8	"	"	"	2.8	0.059	"	+0.008	0.148	0.14	+0.008	
					Mean			0.140	0.14	0.000	
9	B	0.012	0.2	4.6	0.055	0.052	+0.003	0.138	0.13	+0.008	
10	"	"	"	3.5	0.042	"	-0.010	0.105	"	-0.025	
11	"	0.0175	"	3.2	0.056	"	+0.004	0.140	"	+0.010	
12	"	0.021	"	2.5	0.053	"	+0.001	0.133	0.13	+0.003	
13	"	0.020	0.2874	3.7	0.074	0.075	-0.001	0.136	"	+0.006	
14	"	0.021	0.2	2.5	0.063	0.052	+0.001	0.133	"	+0.003	
15	"	"	0.2	2.3	0.048	0.052	-0.004	0.120	"	-0.010	
16	"	"	0.2	2.3	0.048	0.052	-0.004	0.120	"	-0.010	
					Mean			0.128	0.13	-0.002	
17	C	0.012	0.2	7.4	0.089	0.088	+0.001	0.222	0.22	+0.002	
18	"	"	"	7.3	0.088	"	±0.000	0.220	"	±0.000	
19	"	0.021	"	4.4	0.092	"	+0.004	0.230	"	+0.010	
20	"	0.019	0.4	8.7	0.159	0.176	-0.017	0.199	"	-0.021	
21	"	"	"	8.95	0.160	"	-0.016	0.260	"	-0.020	
22	"	"	"	9.2	0.175	"	-0.001	0.219	"	-0.001	
23	"	"	"	9.35	0.178	"	+0.002	0.222	"	+0.002	
24	"	0.021	0.2	6.3	0.097	0.088	+0.009	0.242	"	+0.022	
25	"	"	"	5.2	0.081	"	-0.007	0.202	"	-0.018	
26	"	"	"	5.5	0.088	"	+0.000	0.220	"	+0.000	
					Mean			0.218	0.22	-0.002	

(b.) *Change in Colour in the Cold Solution of Hardening Carbon after Long Standing.*—After long standing at the ordinary temperature the solution of hardening carbon becomes paler, as is shown by the following figures :—

No.	Sample.	Volume of the Solution of Hardening Carbon compared with the Empirical Normal Solution.	
		Directly after Solution is Effected.	After Standing for 24 Hours.
		Cubic Centimetres.	Cubic Centimetres.
1	A	3.0	2.5
2	B	3.2	2.5
3	C	7.3	6.8
4	F	2.9	2.1

The absolute amount of hardening carbon decomposed after standing for twenty-four hours was—

In sample A . . .	$0.14 \times 0.167 = 0.02338$	per cent. of carbon.
" B . . .	$0.13 \times 0.219 = 0.02847$	" "
" C . . .	$0.22 \times 0.069 = 0.02518$	" "
" F . . .	$0.09 \times 0.276 = 0.02484$	" "

(c.) *Change of Colour of the Solution of Hardening Carbon with Increasing Temperature.*—Even on heating to 80° C. the solution becomes paler, the effect being the greater the longer the heating lasts. This is shown by the following figures :—

		Volume of the Sample compared with Normal Solution in c.c. after Heating to 80° for					Intensity of Colour of Solution in Per Cent. after Heating to 80° for				
No.	Sample	0 Min.	15 Min.	30 Min.	45 Min.	60 Min.	0 Min.	15 Min.	30 Min.	45 Min.	60 Min.
1	A*	3.0	2.8	2.6	2.3	2.1	100.0	93.3	86.7	76.7	70.0
2	B*	3.2	2.9	2.9	2.2	2.1	100.0	90.6	90.6	66.7	65.6
3	C*	7.3†	5.5	4.9	4.9	4.6	100.0†	75.3	67.1	67.1	63.0
4	F*	2.9	2.6	2.4	2.2	2.3	100.0	89.6	82.7	75.8	79.3
5	A	3.9	...	...	...	3.2	100.0	...	...	...	82.1
6	B	3.8	...	...	...	3.0	100.0	...	...	...	78.9
7	C	6.3	...	...	...	5.5	100.0	...	...	...	87.3
8	A	3.9	...	2.0	...	...	100.0	...	51.3	...	...
9	B	3.5	...	1.9	...	...	100.0	...	54.3	...	...
10	C	5.2	...	3.0	...	...	100.0	...	57.7	...	...
11	F	5.5	...	2.9	...	...	100.0	...	52.7	...	...
12	A	4.2	...	2.2	...	...	100.0	...	52.4	...	...
13	B	3.5	...	2.3	...	...	100.0	...	65.7	...	...
14	C	5.5	...	3.2	...	...	100.0	...	58.2	...	...
15	F	6.2	...	3.1	...	...	100.0	...	50.0	...	...

For the same duration of heating the increase in colouring, that is to say the loss of carbon, appears to increase with the amount of hardening carbon present, as is shown by the following figures :—

No.	Sample.	Amount of Hardening Carbon in Milligrammes.	After Heating to 80° C. for 30 Minutes.	
			Mean Decrease in Colour. Per Cent.	Loss in Hardening Carbon in Milligrammes.
1	E	0.0355	17.3	0.00614
2	B	0.0520	13.5	0.00703
3	A	0.0560	19.3	0.01079
4	C	0.0880	38.9	0.03426
5	F	0.0920	48.7	0.04476

\* The temperature was below 70° C. to begin with.

† Cloudy ; the cloudiness disappeared on heating.

(d.) *Determination of the Hardening Carbon at 80°.*—The determination of the hardening carbon may also be effected by dissolving the steel in dilute nitric acid in the cold, filtering after the evolution of gas has ceased, through a dry filter paper hardened in nitric acid, and then an aliquot portion of the filtrate, after being heated to 80°, used for the colour comparison. Of course all the samples to be compared must be heated for the same time and to the same temperature, as they would otherwise not be comparable, as previously mentioned. In this way, using 0·2 grammes samples, and 10 cubic centimetres of dilute acid in the solution of the samples, the following values were obtained, and 2 cubic centimetres of the hardening carbon solution being employed in comparing the colour intensities.

One cubic centimetre of the solution, subjected to comparison, corresponds, after heating for about thirty minutes to 80° C., to the following quantities of hardening carbon :—

Samples.	Series of Experiments.		
	1.	2.	3.
A.	Milligrammes.	Milligrammes.	Milligrammes.
B.	0·01914	0·02800	0·02545
C.	0·01793	0·02737	0·02261
	0·01796	0·02933	0·02750
Averages	0·01834	0·02823	0·02519

(e.) *Determination of the Carbide Carbon by the first Method.*—The sample of steel was dissolved in 10 cubic centimetres of cold dilute nitric acid, the carbide carbon collected on a dried filter, hardened in nitric acid, washed with water, and then dissolved from the filter in dilute nitric acid at 80° C., allowed to settle, and an aliquot portion of the solution (2 c.c.) used for the colour comparison. Among others the following values were obtained :—

No.	Sample.	1 Cubic Centimetre. Solution Corresponding with Carbide Carbon. Milligrams.	Weighed out. Grams.	Volume of Comparative Solution. Cubic Centimetres.	Carbide Carbon. Milligrammes.		Difference.	Carbide Carbon. Per Cent.		Difference.
					Colorimetrically.	Gravimetrically.		Colorimetrically.	Gravimetrically.	
1	A	0.024	2.0	57.0	1.368	1.28	+0.088	0.68	0.64	+0.04
2	"	0.024	2.0	55.2	1.325	1.25	+0.045	0.66	0.66	+0.02
3	"	0.020	0.2	13.8	0.276	0.256	+0.020	0.69	0.69	+0.05
4	"	0.0275	0.2918	12.4	0.248	0.248	-0.008	0.62	0.62	-0.02
5	"	0.0275	0.2918	13.1	0.3603	0.3735	-0.0132	0.62	0.62	-0.02
6	"	0.036	0.2	7.4	0.266	0.256	+0.010	0.66	0.66	+0.02
7	"	0.035	"	6.47	0.233	0.233	-0.023	0.58	0.58	-0.06
8	"	0.035	"	7.6	0.266	0.266	+0.010	0.66	0.66	+0.02
							Mean	0.65	0.64	+0.01
9	B	0.020	0.2	20.0	0.400	0.360	+0.040	1.0	0.90	+0.10
10	"	0.020	0.2	19.0	0.380	0.380	+0.020	0.95	0.95	+0.05
11	"	0.0275	0.2874	19.5	0.5363	0.5173	+0.0190	0.93	0.93	+0.03
12	"	0.036	0.2	11.8	0.4250	0.360	+0.065	1.06	1.06	+0.16
13	"	0.035	"	10.26	0.369	0.347	+0.009	0.91	0.91	+0.01
14	"	0.035	"	9.9	0.347	0.347	-0.013	0.87	0.87	-0.03
							Mean	0.95	0.90	+0.05
15	C	0.020	0.2	11.3	0.226	2.284	-0.058	0.57	0.71	-0.14
16	"	0.020	0.2	14.8	0.296	0.296	+0.012	0.74	0.74	+0.03
17	"	0.036	"	8.2	0.205	0.205	+0.001	0.74	0.74	+0.03
18	"	0.035	"	7.54	0.271	0.271	-0.013	0.68	0.68	-0.03
19	"	0.035	"	8.9	0.312	0.312	+0.028	0.78	0.78	+0.07
							Mean	0.70	0.71	-0.01

As the above numbers show, much greater differences result with this method in the case of carbide carbon than in the determination of hardening carbon, partly because losses may exist in filtering off the carbide, but mainly because, in dissolving the samples of steel at a temperature of 80°, different quantities of the dissolving liquid evaporate, according to the duration of the period required for the solution, and the surface of the liquid. In this way the quantity of the solution removed by the pipette from the filter residues does not exactly correspond to the quantity used in the calculation. Further, small quantities of the carbide may remain unnoticed, enclosed by the threads of the filter paper, and consequently too small a quantity of carbide carbon may be found in the solution. To avoid these difficulties as far as possible, as well as to simplify the process, the following second method was adopted :—

(f.) *Determination of the Hardening Carbon and Carbide Carbon Contents in Steel.*—For the determination of the hardening carbon 0·2 gramme of steel is taken, and dissolved in dilute nitric acid in the cold—2 volumes of concentrated acid and 3 of water—that is to say, by placing the dissolving vessel in cold water. The solution is well shaken repeatedly, and when no further evolution of gas can be observed, it is well mixed and filtered through a dry filter without subsequent washing. Two cubic centimetres of the filtrate are used for the determination of the hardening carbon by direct comparison with the normal solution, and another 2 cubic centimetres placed for the time on one side.

In the meantime, for the determination of the carbide carbon, 0·04 gramme of the sample of steel under examination is weighed out for each test, 10 cubic centimetres of the dilute nitric acid, described above, poured on to it, and then transferred to a water-bath at 80°, *simultaneously* with the other 2 cubic centimetres tests solution for hardening carbon which had been placed on one side, as previously mentioned. As soon as complete solution is effected, both series of solutions are compared with the same standard solution, and from the compared volume of the solution of the total carbon, the compared volume of the hardening carbon solution which had been heated to 80° is subtracted. The difference gives the volume corresponding to the carbide carbon, and from this the percentage contents can be readily calculated.

For the purpose of this comparison I use unchangeable empirical standard solutions, consisting of slightly acidulated solutions of  $\text{Fe}_2\text{Cl}_6$  and  $\text{CoCl}_2$ . If it is desired to obtain as great a degree of accuracy as possible, two such solutions can be employed, differing but slightly from each other in their tints.

Should the small tubes used in comparing the colours of the solutions not be of exactly the same width, which may be ascertained by comparing the lengths of their subdivisions, a volume correction may be readily made when it is remembered that the colour intensity of one and the same solution is directly proportional to the square of the thickness of the layers of solution, and therefore inversely proportional to the height of the columns of liquid under comparison.

One series of experiments may be selected from among many others as an example :—

*Carbon Contents determined Gravimetrically in the Samples.*

	A.	B.	C.	G.
	Per Cent.	Per Cent.	Per Cent.	Per Cent.
Hardening carbon . . . .	0·14	0·13	0·22	...
Carbide carbon . . . .	0·64	0·90	0·71	...
Combined carbon, total . .	0·78	1·03	0·93	1·414

(a) *Determination of Hardening Carbon.*—Quantity of sample taken, 0·2 gramme, dissolved in 10 cubic centimetres of nitric acid and filtered; 2 cubic centimetres of the filtrate was compared in the cold, and 2 cubic centimetres after simultaneous heating to 80° with the Eggertz test for carbide carbon. The comparison made in the cold shows:—

	A.	B.	C.	G.
Volume compared . . . .	2·0 c.c.	2·2 c.c.	4·0 c.c.	5·6 c.c.
Factor for correction due to unequal width of the cali- brated tubes . . . .	$\frac{47}{40} = 1\cdot175$	$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$
Corrected volume . . . .	2·35 c.c.	2·20 c.c.	4·00 c.c.	5·60 c.c.

If steel B be taken as the standard steel, one cubic centimetre of the solutions compared correspond to  $\frac{0\cdot13}{2\cdot2} = 0\cdot059$  per cent. of hardening carbon, and one obtains—

	A.	B.	C.	G.
	Per Cent.	Per Cent.	Per Cent.	Per Cent.
Hardening carbon colori- metrically . . . .	0·1387	0·1298	0·2360	0·3304
Difference as compared with gravimetric method . . . .	-0·0013	-0·0002	+0·0160	...

The comparison of the 2 cubic centimetres heated to 80° C. showed:—

	A.	B.	C.	G.
Volume compared . . . .	2·0 c.c.	1·9 c.c.	3·0 c.c.	3·2 c.c.
Factor for correction . . . .	1·05	0·92	1·00	1·30
Corrected volume . . . .	2·10 c.c.	1·73 c.c.	3·00 c.c.	4·16 c.c.

The value of 1 cubic centimetre of the above solutions works out to  $\frac{0.13}{1.73} = 0.075$  per cent. of hardening carbon, and the results are :—

	A.	B.	C.	G.
	Per Cent.	Per Cent.	Per Cent.	Per Cent.
Hardening carbon colorimetrically . . . . .	0.1575	0.1298	0.2250	0.3120
Difference as compared with the result by the gravimetric method . . . . .	+0.0175	-0.0002	+0.0050	...
Average values for the hardening carbon colorimetrically . . . . .	0.1481	0.1298	0.2310	0.3212
Difference from gravimetric results . . . . .	+0.0081	-0.0002	+0.0110	...

(β) *Determination of the Carbide Carbon.*—Weight of sample taken, 0.4 gramme; dissolved in 10 cubic centimetres of dilute nitric acid at 80° C., and compared with the normal solution, showed :—

	A.	B.	C.	G.
Volume compared (total carbon)	15.3 c.c.	21.5 c.c.	17.9 c.c.	25.8 c.c.
Factor for correction . . . . .	1.00	0.99	1.03	1.02
Corrected volume . . . . .	15.30 c.c.	21.29 c.c.	18.44 c.c.	26.32 c.c.
Subtracted corrected volume for hardening carbon . . . . .	2.10 c.c.	1.73 c.c.	3.00 c.c.	4.16 c.c.
Volume of the carbide carbon solution . . . . .	13.20 c.c.	19.56 c.c.	15.44 c.c.	22.16 c.c.

As the value of 1 cubic centimetre of the carbide carbon solution works out to  $\frac{0.90}{19.56} = 0.046$  per cent., one obtains :—

	A.	B.	C.	G.
	Per Cent.	Per Cent.	Per Cent.	Per Cent.
Carbide carbon, colorimetrically . . . . .	0.6072	0.8998	0.7102	1.0194
Difference as compared with the gravimetric result . . . . .	-0.0328	-0.0002	+0.0002	...

Finally, the total percentage of combined carbon is found to be as follows :—

	A.	B.	C.	D.
Hardening carbon (mean) . .	Per Cent. 0·1481	Per Cent. 0·1298	Per Cent. 0·2310	Per Cent. 0·3212
Carbide carbon . .	0·6072	0·8998	0·7102	1·0194
Combined carbon, colorimetrically . .	0·7553	1·0296	0·9421	1·3406
Combined carbon, gravimetrically . .	0·7800	1·0300	0·9300	1·4140
Difference . .	-0·0247	-0·0004	+0·0112	-0·0734

(γ.) *Final Remarks.*—The results recorded show that the determination of the hardening carbon and carbide carbon may be easily and rapidly effected by the colorimetric method with satisfactory results. There are, nevertheless, some points of difficulty connected with the general employment of this method, to which reference must be made. One of the most important sources of error is the liability of the carbide to be attacked by acids, to which F. Mylius, F. Förster, and G. Schoene \* have recently pointed out. This leads to difficulty, in that it is a somewhat difficult matter to obtain standard steels with percentages of hardening and combined carbon exactly determined.

The solution, too, of the carbide carbon in dilute nitric acid is not constant. Thus, after standing for a long time, the diminution in carbide carbon—in milligrammes—shown in the following table was noted :—

Sample.	Milligrammes of Carbide Car- bon in 1 Cubic Centimetre.	Decrease in the amount of Carbon in Milligrammes after standing for			
		20 hours.	24 hours.	26 hours.	48 hours.
A	0·262	...	0·014	...	...
"	0·360	0·015	...	0·013 (0·028)	0·007 (0·035)
B	0·380	...	...	0·000	...
"	0·536	0·044	...	0·052 (0·096)	0·020 (0·116)
E	0·049	...	0·015	...	...

As will be seen, this diminution is however so slight, that allowing to stand even for many hours leads to no error in the result.

It is different, however, with the case of the solutions of hardening carbon. As has been already pointed out, these diminish in

\* *Loc. cit.*

intensity of colour both on heating and on long standing in the cold, apparently to the greater extent the more hardening carbon is present. But even on dissolving, a portion of the hardening carbon increasing with the percentage appears to escape or at least to be converted into colourless compounds. This, at least, seems to be borne out by the fact that in the examples given under (*f*) the total carbon contents in sample G were found considerably too low—0·0734 per cent.—as it is just this sample which contains far more hardening carbon—0·32 per cent.—than the others. A further example is afforded, too, by the sample D, kindly supplied by Professor Ledebur, for which the following values were obtained:—

No.	Hardening Carbon, Per Cent.			Carbide Carbon, Per Cent.		
	Colorimetric.		Difference.	Colorimetric.		Difference.
	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.
1	0·3730	0·55	-0·1770	0·4345	0·38	+0·0545
2	0·3940	"	-0·1560	0·4066	"	+0·0256
3	0·3677	"	-0·1823	0·4042	"	+0·0242
4	0·3730	"	-0·1770	...	...	...
5	0·3568	"	-0·1932	...	...	...
Mean	0·3729	0·55	-0·1771	0·4147	0·38	+0·0347

Unfortunately, it has not been possible for me to obtain other hardened samples to further investigate this question. Still, it appears advisable to use for samples of hardened steel, standard hardened steel of similar composition. This behaviour throws fresh light on the ordinary Eggertz test, inasmuch as it affords an explanation of the need of several standard steels, even when the solution is effected at 80° C.

*CORRESPONDENCE.*

Mr. H. KELWAY BAMBER pointed out that the great drawback to the use of Eggertz' colour tests for steel was that it was always necessary for the standard and the steel to be tested to be of exactly the same kind and composition, or the results would be valueless. For chemists at works where the same kind of steel only was made, and rapidity and approximate results were chiefly required, it was useful. No doubt carbon existed in steels in different forms, but had it ever been proved what was the state of existence of the different kinds of carbon in steel?

To say that the carbon that caused hardness in steels was that which was given off as hydrocarbons when the steel was attacked by dilute acids was probably an idea only. If drillings of different kinds of steel were treated with dilute nitric acid, 1 to 20 in the cold, mild steels (up to 25 per cent. carbon) would be acted on rapidly with rise of temperature, and most of the carbon, if not all, would pass off as gas. If this was the "hardening carbon," how was it they were soft steels? Rails with about 0·40 per cent. carbon would be much less acted on by that acid, and hard steels 0·90 per cent. to 1·20 per cent. of carbon would show no effervescence at all, but the carbon would at once begin to separate, making the drillings appear black, and in twenty-four hours all the iron would have been dissolved, leaving the carbon as a black residue, which could be filtered and determined by combustion with accurate results, the filtrate being almost colourless, having a slight greenish tinge only. If, however, drillings of mild steels were first treated with very dilute nitric acid, 1 to 160, only the slightest sign of effervescence would take place, but carbon would begin to form on the surface of drillings, and that appeared to have a protecting effect on the steels, for after that weak acid had acted for three or four hours, the stronger acid (1 to 20) might be used to complete the solution, and the action would go on as if it were hard steel.

If the "hardening carbon" was that which was given off as hydrocarbons, it would appear as if those very hard steels had no hardening carbon; in what form, therefore, was the

carbon that caused them to be almost too hard to drill ? The effect of varying strengths of acids on steels being so irregular, was it safe to state that the action of acids on steels would show which was hardening carbon, which was carbide carbon, &c., &c.? In high carbon steels the carbon separated into flakes, and in other steels in the form of finest powder. Was not the carbon in white iron all dissolved in the iron in the same way as salts were dissolved in water ? The act of separation at different temperatures and under different circumstances was very similar. A hot saturated solution of sodium sulphate might be cooled down to the temperature of the atmosphere without separation of any of the salt in the absence of vibration ; but after having been in this condition for hours, on the slightest vibration, such as a person walking across the room, instant solidification would take place with considerable rise of temperature. Was not that somewhat similar to what took place in the cooling of steels ? When certain substances crystallised out, the fall of temperature was arrested, or even raised further, and again decreased, until another substance crystallised out with similar effect as to variation of temperature ? Again, a solution of ammonia magnesium phosphate might be kept clear until it was beaten with a glass rod, when the salt at once began to separate. Was not that similar to the separation of carbon from steel in the process of hammering and rolling ?

The carbon which was given off as hydrocarbon when steel was treated with dilute acids would be in chemical combination with the iron or other substances ; for free carbon would not be likely to be formed into hydrocarbon in the circumstances.

Mr. R. A. HADFIELD, Member of Council, said, that as the subjects of the author's papers more or less related to those which he had dealt with when discussing Mr. Royston's papers, and as he had there referred fully also to the Baron Jüptner's papers, he would only briefly add that he thought they were much indebted for the author's further valuable research work. As he had before stated, he believed that with the physicist to give them his results, and the chemist to tell them what had been the chemical nature of the changes, they would advance a long way towards a more satisfactory state of knowledge

regarding the changes which resulted in iron and steel by thermal and other treatment.

To him the papers of Mr. Royston and Baron Jüptner seemed to be so interdependent that it might have been well if one discussion could have embraced the whole. If Mr. Royston's samples could have been treated by the chemical methods now referred to, more light would have been thrown upon the subjects with which he had dealt. The examination of steel was growing each year more complex; hence the importance of correlation, necessarily including mechanical, chemical, microscopical, and thermal treatments of each individual specimen.

Mr. Osmond, in some recent good-humoured criticism and comments upon a contribution of his (Mr. Hadfield's) to the American Institute of Mining Engineers, said he at once seized upon every fact relating to carbon experiments; but must it not necessarily be so when each year fresh facts brought to light and submitted for examination only went to prove, as it seemed to him, the vital importance and effect of carbon upon iron and steel combinations? He referred to that because of the important statement in the author's paper. They all knew the great importance and strong influence of phosphorus, and, as the author had pointed out, notwithstanding that importance, its influence could hardly be compared with that due to carbon. What was equally important in the same direction was that the author's results also proved that the phosphorus, instead of delaying the action of carbon, as it should do under the "atomic volume theory," if anything decidedly increased the effect of hardening carbon.

He thought they were much indebted to the author for his exceedingly able researches, both as regarded the determination of hardening carbide carbon and the influence of phosphorus on cold-shortness. He sincerely hoped that he would continue his important work upon certain definite specimens, of which they had both the mechanical, physical, micro-structural, and other effects, so as to secure thorough correlation.

Mr. F. OSMOND, on behalf of Mr. Werth and himself, thanked the author for the attention he had given to their experiments on the Eggertz method. The determination of carbon in its

different forms was certainly of the greatest interest to the metallurgist, and much praise was due to the author for his investigations in that direction. The whole question was one of considerable difficulty. As a rule, in analytical methods, either the element itself or some substance containing a definite proportion of it was at hand; but hardening carbon had not been isolated, and even its very existence had been contested. Mr. Sauveur, for instance, thought that it might be nothing more than carbide carbon in a very fine state of division. In order to procure standards, it was, therefore, necessary to have recourse to an indirect process, and to calculate the hardening carbon by difference after directly determining the carbide carbon. Up to the present, however, this latter determination was itself uncertain, and could not be verified exactly. That fact had faced him (Mr. Osmond) and his friends, and had prevented them from obtaining a practical application from their results. Possibly these difficulties did not now exist. Mr. Moissan appeared to have found a method of purifying the carbide  $\text{Fe}_3\text{C}$  by treating the residue from solution in fuming nitric acid. In this way a good foundation was obtained for the estimation of the carbide, and indirectly for that of hardening carbon. Care would still have to be taken, however, as the carbide,  $\text{Fe}_3\text{C}$ , had not always the same chemical properties. When the electrolytic method was used, the independent cementite was attacked, and only that of the perlite was isolated. That, he said, suggested two isomeric forms of  $\text{Fe}_3\text{C}$ , and those two forms might not behave similarly in nitric acid. That, therefore, it would be necessary to verify. He (Mr. Osmond) and Mr. Werth had also been troubled by those greenish colorations which Eggertz solutions assumed in the case of hardened steels, as mentioned by the author. The phenomenon appeared to them to be very irregular and capricious; it occurred or was absent under apparently identical conditions, and the reason was not known, nor even surmised.

Mr. ERNEST H. SANITER said it appeared to be proved from the author's interesting research that hardening carbide was entirely soluble in dilute cold nitric acid, to which it gave a colour, which, however, did not always appear to be in proportion to the amount of hardening carbide present (samples D and G).

That, however, might be remedied by using a standard containing approximately the same amount of hardening carbide as suggested by the author. That brought them to the difficulty of preparing a standard. It was well known, when steel was dissolved by Müller's method, that as soon as all the free iron was in solution, the carbide was attacked with consequent loss of carbon. He presumed the author's gravimetric carbide carbon results were obtained by that method, and that his gravimetric hardening carbide results were by difference. The comparison of the gravimetric with the colorimetric results, when the colorimetric results were obtained by a standard prepared as above, could not be regarded as very convincing in the case of A and C samples when B was the standard, and in the case of D and G the comparison broke down entirely. Another important point which presented itself was whether the carbide carbon was entirely insoluble in cold dilute nitric acid?

Taking sample A as an instance of the importance of this point, if the gravimetric result for carbide carbon was somewhat low, which was not improbable, and the carbide carbon was slightly soluble in cold dilute nitric acid, the two errors would balance each other, and might give a result similar to A.

He would like to know whether carefully annealed steel showed any colour by the cold nitric acid test? How the manganese carbide in the steel behaved to cold nitric acid? and finally he would suggest for the author's consideration whether a method for estimating the hardening carbon with rapidity and ease might not be based on a table of ratios of total carbon to the result obtained on highly chilled steel, such as that given by Hogg.\*

It would, he said, be necessary to have those ratios confirmed. Assuming that those highly chilled steels contained all the carbon in the hardening state, he would proceed in the following manner:—The sample of chilled or partially chilled steel for analysis would be divided into two portions, the one of which would be heated to a bright red, and allowed to cool slowly. The pieces would then be tested in the ordinary way by the Eggertz colour method, selecting as a standard an annealed steel of about the same percentage of carbon, the ratio of the

\* *Journal of the Iron and Steel Institute*, 1897, No. II. p. 183.

total combined carbon to the result obtained by the Eggertz method in its highly chilled state having been previously ascertained in the standard steel.

Taking Hogg's figures for a standard :—

Total Carbon.	Colour Test on Chilled Steel.	Missing Carbon.
0·84	0·35	0·49

And using these figures as a standard on a partially chilled steel, say, they would get the following figures :—

Carbon as shown by Eggertz test . . . .	Annealed Portion. Per Cent.	Partially Chilled. Per Cent.	Missing Carbon. Per Cent.
	0·84	0·60	0·24

Then as 0·49 per cent. missing carbon = 0·84 per cent. hardening carbon

Therefore 0·24 " " " = 0·41 " " "

Mr. J. E. STEAD, Member of Council, thought that this paper, like the last, was a most valuable one, and contained a large amount of original research, and he suggested that it should also be handed to the chemists of large manufacturing departments, and should be studied by all analysts who were interested in the constitution of iron and steel, and that they should follow up the research, and ascertain its practical value. He said it was premature at present to discuss the various points so ably given by the author, but hoped that in, say, a year or two, the results of other workers would be presented to the Institute.

## ON THE GENERAL UTILITY AND ECONOMY OF CENTRAL BLAST CUPOLAS.

BY THOMAS D. WEST, SHARPSVILLE, PENNSYLVANIA.

SOME three years ago the author introduced in cupola practice an improvement, which consisted in providing a central tuyere coming up through the bottom of the cupola in conjunction with outside tuyeres for the purpose of improving the distribution of blast. The results of the experiment were so favourable that greater economy and cleaner working were obtained than in any other form of cupola known to the author. He therefore continued to use it, trying different modifications to ascertain what might be achieved in different conditions of cupola practice.

The advantage of having a tuyere carrying blast up through the centre of the cupola will be obvious to any one who closely watches the action of cupolas as the last charge approaches within 4 or 5 feet of the outside tuyeres. He will then see that the greatest heat and flame is obtained right above the tuyeres at the outer circumference of the fuel, the central portion being left much less active in live combustion. Moreover, by watching the blast blowing-in into the bed of fuel before any iron is charged, he will notice a similar action. Again, another test is to stand inside a cupola after the bottom plate is put up, before any fuel is charged in. The blast is then allowed to enter with all its force, and a handkerchief may be held in the hand at some distance from the tuyere entrance without being moved by the blast. This last test will be a source of surprise to many, as frequently in large cupolas a handkerchief will not be affected by the blast if held a foot away from the cupola walls.

The advantages consist in permitting a more uniform distribution of the blast throughout the fuel in the cupola, and also in permitting the use of a greater volume of blast with a decrease of pressure. This with cold blast is less effective in choking the tuyeres or in chilling the fuel round and in front of the

PLATE XIV.

2.

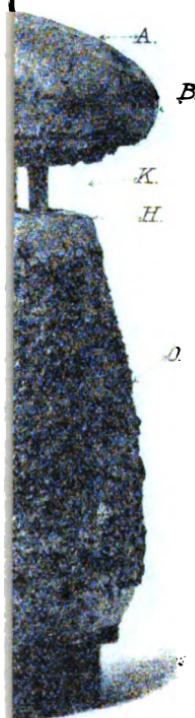


Fig. 3.

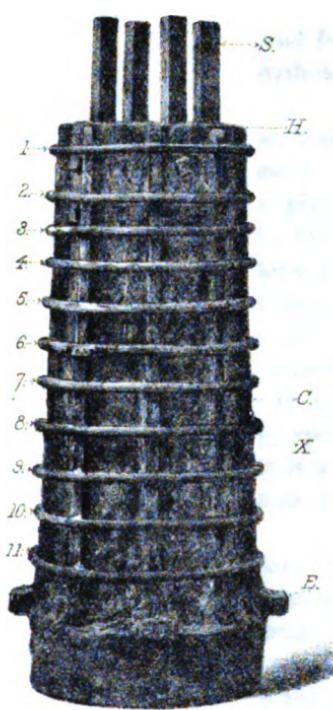
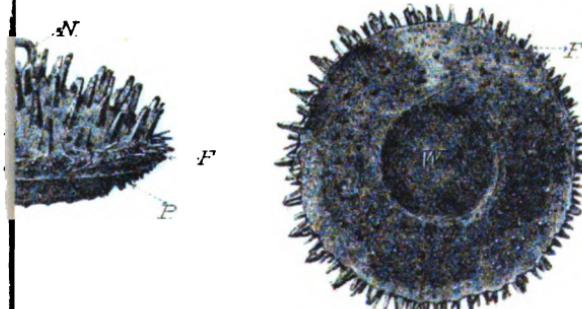


Fig. 4.





tuyeres. The author's experience with central blast clearly shows that, for economising fuel and for securing clean and fast melting, it is not so much the pressure but a well-distributed volume of blast that is necessary.

This feature is confirmed by the fact that in several blast-furnaces in the United States the output is being increased by a larger number of tuyeres having been put in, so as to give a better distribution of blast. Grace Furnace, at Briar Hill, Ohio, has increased its daily output from about 270 to 300 tons, the increase having been brought about by the tuyere space having been divided so as to insert the tuyeres closer together and to increase their number from eight to twelve. Before the number of tuyeres was increased their pressure ranged from 15 to 18 lbs., but with the greater tuyere area it fell about 2 lbs. The speed of the engine was kept the same, so that it is evident that it was a better distribution of blast volume, and not pressure, that was wanted in this case to give the best results.

The theoretical percentage of fuel said to be necessary for melting one ton of iron in a cupola is 59 lbs. Experience shows, however, that if a ton of iron can be melted with an average of 200 lbs. of coke or coal, good work is being done. The uneven distribution of the blast is the greatest drawback to obtaining the best economy of fuel. If it were possible to place fuel on grates in a cupola, and then to have blast enter in equal volume all over the area of the cupola, as is done with grate bars in boilers with closed ash-pit and forced draught, and further, if it were possible to generate carbonic anhydrate in the upper strata of escaping gases by admittance of the air on the plane of the upper tuyeres in cupolas as uniformly as the air could be admitted up through the grate, it might then be expected that the melting would be achieved with the theoretical quantity of fuel necessary. As, with the present state of knowledge, this is impossible, it is necessary to return to the central blast combined with outside tuyeres, an arrangement which is claimed by the author to be the most economical for such purposes.

Since the author has introduced central blast in cupola practice, others have adopted the principle by using central blast alone, that is to say, independently of outside tuyeres. It is obvious, however, that this plan prevents the even distribution

of blast that is desirable, and, moreover, the central tuyere would soon be so choked as to retard or to wholly stop the melting. In all cases where cupolas have an inside diameter of more than 50 inches, whether they run short or long heats, the central blast should be combined with outside tuyeres. Cupolas that are not expected to run much over an hour, and are of smaller size, may economically be worked with central blast alone. In no case, however, where heats have to be longer than an hour and a half, is central blast to be recommended to be used alone. The best results are obtained with central blast cupolas of a larger size.

#### ECONOMY.

The sources of economy obtained by the use of the central blast, with outside tuyeres, may be enumerated as follows :—

1. Greater economy in fuel.
2. Less destruction of lining.
3. Increased speed of melting.
4. Saving in labour in preparing a cupola and in shovelling out refuse.
5. Less waste of chilled iron and fine shot.
6. Greater absence of flame escaping from the stack at the closing or other parts of a heat.
7. Less absorption of sulphur.
8. Greater freedom for the admission of blast, and less labour in keeping the tuyeres open ; and
9. As hot and clean iron is obtained at the end of heats as at the beginning.

The first result is brought about by there being less space for fuel in the body of the cupola below the level of the tuyeres, and by there being a more uniform distribution of the blast throughout the fuel, and, again, by the tuyere openings being freer to admit the blast. Moreover, the fact that the central tuyere openings are at a higher level than the outside tuyeres causes the carbonic oxide formed in the lower portion of the cupola to be reduced to a greater quantity of carbonic anhydride. The saving of the linings is due to there being a less force of blast, or, in other words, less volume of carbonic anhydride, playing against the lining, owing to its being distributed more

uniformly throughout the body of the fuel in the cupola. The speed of melting is increased owing to the fact that there is greater freedom for the admission, and more uniform distribution, of the blast throughout the fuel. There is also a smaller quantity of carbonic oxide escaping. Labour is saved because less chilled material is formed round and in front of the tuyeres, owing to a more uniform distribution of the blast. Another reason for economy in labour is that there is less burning out of the cupola linings, and less refuse to be shovelled out from under the cupola at every bottom drop. The lessened waste in chilled iron and fine shot is due to the higher temperature during and at the end of a heat largely preventing or melting away what chilled stock may have gathered round or in front of the tuyeres during the process. Moreover, the milder distribution of blast throughout the fuel does not give rise to excessive bodies of dead or chilled material in front of the tuyeres to adhere to the sides of the cupola, and so to lessen the melting area. The greater absence of flame at the charging door and stack is due to the more thorough combustion in the melting zones, owing to the fact that the carbonic oxide formed in the lower portion of the cupola is more completely converted into carbonic anhydride before it reaches the charging door. This is so distinctly marked at the end of a heat that the blast may not cause the least sign of flame to emanate from the stack, provided that the central tuyere has its blast properly regulated, in order to prevent it becoming choked. By proper manipulation of the blast-valves, the combustion can be made so perfect that at the end of an operation the intense heat at the melting zone will prevent a look into the cupola, and but little sparks or flame will be seen escaping at the stack. Less absorption of sulphur is caused in a similar manner. The more sulphur there is in fuel, the more can iron be expected to absorb; and it follows that the less fuel there is used, the less sulphur may be expected to be absorbed by the iron, owing to the central blast, diminishing the ratio of the fuel to the iron extracted, and giving hotter iron. The greater freedom for admission of the blast, and the less labour involved in keeping the tuyeres open, is the result of there being less chilled iron and refuse collected in front of the tuyere openings. The increased fluidity of iron is due to the more perfect

combustion and to the walls of the cupola being brought up to a higher uniform temperature throughout the body of its lining. It is also due to the greater freedom from chilled or dead material collected round and facing the tuyeres, diminishing the

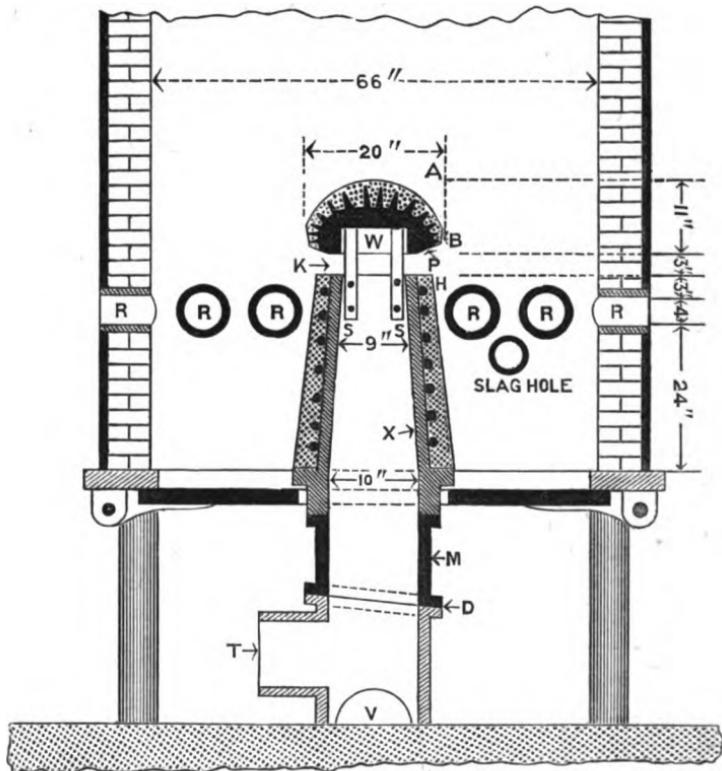


FIG. 1.—West's Permanent "Centre Blast" Tuyere Cupola

area of a cupola available for live fuel during the progress and end of a heat.

#### CONSTRUCTION OF CENTRAL BLAST CUPOLAS.

In the latest form of central blast cupola adopted by the author, the central tuyere is so designed as to form a permanent structure which remains in its place when bottoms are dropped. Its construction is shown in Figs. 1, 2, 3, and 4 (Plate XIV.). It is obvious

that such a design would be unsuitable for cupolas under 50 inches in inside diameter. Illustrations of designs suitable for smaller cupolas have been published in the author's treatise on the "Metallurgy of Cast Iron." In all cases it is of the utmost importance to have outside tuyeres in addition to the central one.

Some difficulty has been experienced by iron founders, who have adopted central blast something after the author's design, with the burning out of the covering cap shown at A (Fig. 1). The author has no knowledge of the type of cap used in these cases. At his own foundry, however, he has had the same cap casting in use in the 66-inch cupola (Fig. 1), running daily heats ranging from 50 to 70 tons, since October 1896 up to the present time (March 1897), and it is in as good condition as it was when first put in position, and its design has not given rise to the slightest trouble.

Many imagine that, on account of its being incased in the centre of a cupola surrounded by incandescent fuel and molten iron, the central tuyere would be unable to resist for any length of time the heat surrounding it. A study of the conditions obtaining shows, however, that when all is working regularly such a tuyere is not subjected to a temperature high enough to burn or melt the tuyere lining. In fact, the temperature at the lower portion of the central tuyere is not much higher than that to which the lining of the ladle holding molten metal is exposed. It may also be said that as long as the top of the covering cap is not extended too high above the level of the outside tuyeres, it is not subjected to a much higher temperature than the lower portion. One reason, no doubt, why many have experienced trouble with covering caps is that they have carried them up too high, so as to bring them up close to the melting zone. The central tuyere's blast opening should never be carried more than 3 to 6 inches above the level of the outside tuyeres.

In order to still further obviate any danger of injury to the cap, the author has adopted, with complete success, a method of charging, which consists in placing the first charge of iron in the form of a circle, with a hole in the centre equal to the diameter of the covering cap. This is then filled with fuel (see Fig. 5), instead of having the centre all iron, as well as the outer portion, as is the usual practice.

It is also advisable to protect the edge at B (Figs. 1 and 2) by placing, as shown at F (Fig. 4), pieces of  $\frac{1}{4}$ -inch round iron

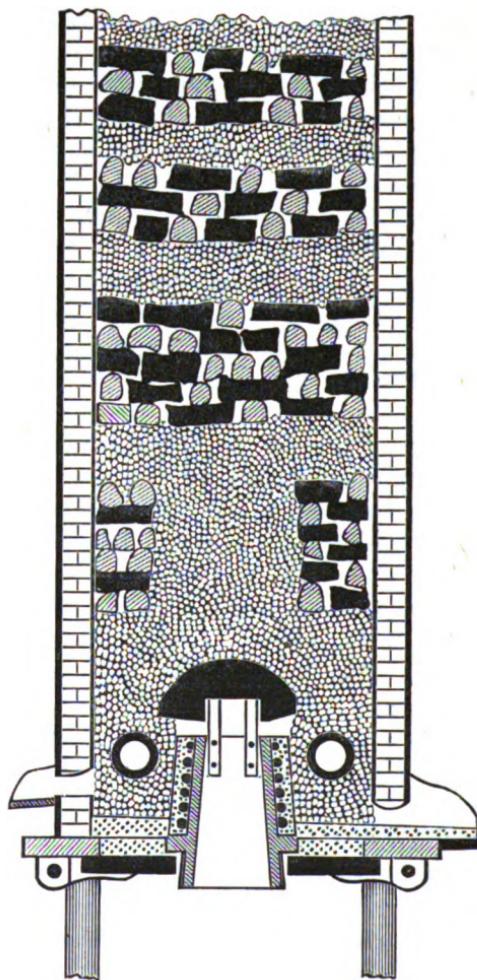


FIG. 5.—Plan for Charging the Bed of Central Blast Cupolas.

and nails, projecting about an inch, placed together as closely as they can be cast in, and then daubed over with clay. Not only is the edge of the covering cap protected in this way, but

the whole body of the casting is prepared in a similar manner. The iron prickers shown should project 2 to 3 inches from the body of the cap casting. The casting should not be less than  $1\frac{1}{4}$  inch in thickness at any part; it should be 3 to 4 inches larger in diameter than the top of the central tuyere at H, in order to prevent molten iron dropping from the cap and leaking into the tuyere. The space between the cap and the top of the central tuyere for the admission of blast should be  $2\frac{1}{2}$  to  $3\frac{1}{2}$  inches; the longer the heats the greater should be the width of the opening. The under side of the covering cap at P (Figs. 1, 2, and 4) may have short projections of about  $\frac{1}{2}$ -inch cast on it, and daubed over with clay. But as the cold blast is constantly playing against this surface, there is little danger of it becoming too hot if cupolas are kept fairly steadily in blast. In cases where they are left to stand an hour or two without the blast being on, it is advisable to prepare the under side of the cap as described. In order to support the cap in place,  $1\frac{1}{4}$ -inch pieces of square wrought-iron bars are bolted to the central tuyere, as shown at S (Figs. 1 and 3). A recess of about 3 inches deep is cast in the cap-piece (Figs. 1 and 4). This recess, being circular, permits the cap to be fitted over the  $1\frac{1}{4}$ -inch support (Figs. 1 and 3) at any point, in order to enable it to maintain its position during a heat. Where heats might be extended to exceed six hours' duration, an excessively "hot iron" required, it would be well to make this recess having a solid centre, as seen at U, Fig. 6, which then leaves an opening at Z to admit the entrance of the four  $1\frac{1}{2}$  square bars seen at S, Figs. 1 and 3. Such a construction in the recess would prevent the bending inward of the bars S, should they become heated red-hot from any cause. The dimensions given with Fig. 6 show that of the pattern from which the covering cap is moulded before the "prickers" for holding the clay are attached to the mould. The test applied at the author's foundry has been a severe one, for the lengths of heat are not merely of an hour or so duration, but range from four to five hours. The results tend to show that central blast, as described above, might be made to run day and night with perfect safety for a week at a stretch, as is necessary in running cupolas in Bessemer practice.

It will be noticed that, for the sake of clearness, the connections for bringing the blast to the outside tuyeres are not shown

in Fig. 3. It is, however, necessary that dampers or valves must be provided, so that the central and outside tuyeres can be worked together or separately, so as to regulate the blast-pressure at will. Where long heats are run there is a liability of the central tuyere chilling the stock at K. This difficulty can readily be obviated by shutting off the blast for a short time from the central tuyere, so as to permit the heat of the cupola to melt any chilled material that might be clogging the opening of the central tuyere at K. Sometimes a piece of half-melted iron may lodge in front of the opening at K, and obstruct the fluid iron in its direct descent to the hearth of the cupola. The escape of sparks, &c., down a central tuyere caused in this manner can be stopped almost instantly by increasing the blast-pressure in the central tuyere. The door V is so arranged as to be readily opened or closed, in order to permit the removal of any iron or slag that may have penetrated to the bottom of the shaft of the central tuyere.

Some little experience is necessary to work central blast to the best advantage; with a little practice, however, the manipulation is soon acquired. When a new cupola is to be designed with central blast, it is best to have the outside tuyeres continuous in their opening, as in the Mackenzie cupola, in place of pocket tuyeres, as shown in the round form depicted in Fig. 1. A better distribution of the blast round the outer circle of the fuel is thus effected.

The central tuyere itself can be made all of cast iron, or of boiler plate. For a permanent structure a cast-iron tuyere is preferable, as it presents greater rigidity, and as it is made at less cost. The central tuyere, as at X (Figs. 1 and 3), is made about an inch thick, with ribs throughout its length on the periphery (as shown at C, Fig. 3), in order to sustain wrought rings of  $\frac{3}{4}$ -inch iron for supporting the clay, which is about 3 inches thick. These rings are shown in position in Fig. 3. Cast-iron projections or prickers have been tried in place of these rings, but the inconvenience of casting them on to the body of the tuyere renders them undesirable. Fig. 2 shows the central tuyere, with its covering cap daubed over with clay ready for a heat, or as they would appear in position on the base in Fig. 1. The base is made in sections, so that the section M can be removed if anything goes

wrong with the central tuyere. The main body of the tuyere could then have its lower portion stopped with clay, it being necessary for this purpose to place a large lump on a plank levered so as to press it upwards into the interior. It would then be tightly closed against the ascent of iron or blast, and the heat could be finished by the use of the outside tuyeres only. It will, of course, be understood that this is only a precaution against an accident that might never occur.

With central blast the author has effected at his foundry a saving in fuel of over 30 per cent. Apart from this economy, the advantages enumerated at the beginning of this paper are sufficient to warrant the adoption of central blast. The type of cupola used at the author's foundry is shown in Fig. 1, the dimensions on the right side indicating the height at which the openings of the central and outside tuyeres are placed.

The outside tuyeres were recently raised about 6 inches. This enabled the cupola to contain a larger mass of metal, and at the same time there was more space between the slag-hole and the outside tuyeres. The change resulted in an increased speed in melting, and in cleaner working. Where long heats have to be run it is specially important to have a good space between the slag-hole and the outside tuyeres, as, when they come close together, it brings the slag up to a level where it is readily chilled by the incoming cold blast from the outside tuyeres. This may eventually lead to the tuyeres becoming choked.

In conclusion, the author would point out that this paper is merely a supplement to his previous writings on the same subject. He trusts, however, that the new illustrations and descriptions he now brings forward may afford further proof of the general utility and economy of central blast for cupolas, and also lead to its more general adoption.

*CORRESPONDENCE.*

Mr. R. A. HADFIELD, Member of Council, thought that although the author's paper might not give rise to any considerable discussion, the members of the Institute would be glad to have the important subject of improved cupola practice brought before them for consideration. There was still in ordinary practice much that was empirical, and, therefore, any new system or discussion of present methods should prove a valuable addition to the somewhat meagre knowledge possessed on the subject.

The cupola was, perhaps, the most economical apparatus in use for effecting fusion, but owing to the difficulty of comparing ideas as to the best methods of its management upon a scientific basis, it was, he thought, still far from being under proper control. There were few who could, by its aid, produce absolutely uniform meltings, at any rate for special work, and it was often for that reason that there was so much uncertainty in iron-foundry practice in obtaining uniform results. The results of long experience by rule of thumb had enabled good results to be obtained, but with more scientific knowledge brought to bear, very considerable improvement and greater use for that method of melting would be found.

As a rule, ordinary iron-foundry practice was uncertain, partly because of the great variation in raw material supplied to the melter. At few iron-foundries was there, he believed, chemical knowledge brought to bear on the daily working; hence the great importance, when dealing with the many grades and qualities of iron presented to the foundry manager, of reducing errors resulting from the working of the cupola itself as far as possible. He thought, therefore, the author's improved design and practice deserved encouragement, and in one direction, at any rate, he seemed to have effected considerable improvement, though it would have been interesting to have had more chemical details of his results—*e.g.* the reduction in the absorption of sulphur. That element acted very prejudicially, and if, therefore, a centre-blast cupola made it possible to obtain a purer material, the

author would have rendered an important service. Perhaps at a later date he would be able to give the Institute fuller details of his results in that direction.

He understood that some users in America who had tested the central blast system had found considerable difficulty in keeping the head or covering cap intact for a sufficient length of time. It certainly seemed to him that the ordinary charging operations, usually carried out in the roughest possible manner, would be very liable to cause damage to the covering cap. It would be interesting, he thought, to have reports on that point from several users giving their general experience.

He thought their special thanks were due to the author for the trouble he had taken in bringing the subject before the Institute, and he hoped that they would hear more about the development of his methods, which seemed to offer a number of important advantages in which all iron-founders were interested.

## ON THE AGRICULTURAL VALUE OF SULPHATE OF AMMONIA FROM BLAST-FURNACES.

BY F. J. R. CARULLA, F.C.S., CHAIRMAN OF THE NOTTINGHAM SECTION OF THE  
SOCIETY OF CHEMICAL INDUSTRY.

THE hazy ideas that prevail on the subject of nitrogenous manures amongst farmers seems to call for more accurate knowledge on the part of those who produce these commodities, in order that they may be able to educate their customers. It is therefore especially necessary for ironmasters, who have now become such large makers of sulphate of ammonia, that they should harbour no doubts as to the true value of this product as a fertiliser for agricultural purposes. The nitrate of soda producers have by their most praiseworthy efforts succeeded in creating quite a literature on their special subject, and sulphate of ammonia is being left behind, more because nitrate of soda is so persistently pushed to the front, than because of any inherent deficiency in its intrinsic value. Meanwhile many sulphate of ammonia makers quietly accept the situation without protest, some indeed almost appearing to be converted to the new theories.

Until very recently, it was always acknowledged that  $\frac{3}{4}$  cwt. of sulphate of ammonia was equal in fertilising power to 1 cwt. of nitrate of soda, or, to be perfectly safe, say that 4 cwts. of sulphate equal 5 cwts. of nitrate. However, since the iron blast-furnaces have begun to send their make into the market in increasing quantities, the intrinsic value of sulphate of ammonia as a fertiliser appears to have so diminished as to have become equal to that of nitrate of soda, weight for weight. Surely no one will say that this can be due to any inferiority in the product from blast-furnaces. Yet the increased make and the apparently diminished intrinsic value are contemporaneous events that would lead a superficial observer to that supposition. It is easy to say that over-production is at the bottom of the mischief; but that is not all. You know the story of the man who, although never having smelt the smoke of powder, recounted his numerous achievements in battle, until he really came to believe

himself the hero of them. In the same manner our friends the nitrate of soda producers have gradually won for themselves a position of pre-eminence that they now stoutly try to maintain, and do so successfully at the present moment.

No less an authority than the Secretary of the Permanent Nitrate Committee, replying to certain correspondence on the subject of sulphate of ammonia as a fertiliser, says in the *Birmingham Daily Post* of February 20, 1897: "For the majority of purposes, nitrate of soda, weight for weight, is practically of greater value to the farmer than sulphate of ammonia." You will thus see that the point has not been overstated, for sulphate of ammonia has not fallen from its former position to be the equal of nitrate of soda, but has even come to be regarded as its inferior. The public seems to share in this belief, for it gladly pays more for nitrate of soda than for sulphate of ammonia, so great is the power of advertisement.

It will occur to any one who gives the matter careful thought that no better proof could be adduced of the equal intrinsic worth of the unit of nitrogen in the two manures than the fact that no difference is made between them in the Fertilizers and Feeding Stuffs Act, passed in a recent session. If there really be any material difference between them, and the unit of nitrogen in nitrate of soda is really worth more than is the same unit in sulphate of ammonia, what can the Nitrate Committee have been doing to allow the bill to pass through Parliament without protest? It was not a bill of which they could have been ignorant.

This view was first promulgated during a discussion before the Nottingham Section of the Society of Chemical Industry at Burton-on-Trent in January last, a report of which appeared in the daily press and in a number of technical papers. Expression has been given to it, besides, in the newspapers since that date whenever opportunity has offered. No reply has, to the author's knowledge, been vouchsafed to the argument, and he therefore ventures to advance it as an important proof of the equal value of the unit of nitrogen in the two fertilisers.

It may here be mentioned that Mr. James O'Sullivan, during the discussion referred to above, expressed the opinion that the great obstacle to the spread of the use of sulphate of ammonia

in this country was its name, and that if it could be re-christened, so as to convey the idea of nitrogen in the same way that the word nitrate does, it would be a good thing. Accepting this view as in some measure explaining the anomalous position of the two fertilisers towards each other, the author suggested that sulphate of ammonia should be called "Nitrogenous Sulphate" for the purpose of its sale amongst home-farmers. No one would be able to say that he is in any way misled ; for a substance that contains in any given weight upwards of 25 per cent. more nitrogen than is contained in the same weight of nitrate of soda, and which is besides the richest nitrogenous manure available, is surely entitled to be so called. When one considers how successful the application of suggestive names has been in other departments of industry and of commerce, it must be admitted that the neglect of sulphate of ammonia, with its nearly 21½ per cent. of nitrogen, for nitrate of soda, that barely contains 16½ per cent., may in part be due to prejudice created by the persistent drumming of the nitrogen idea on behalf of nitrate of soda, which a change of name, making it also prominent for sulphate of ammonia, might remove.

It will naturally be asked what is the result of comparative experiments made with the two fertilisers ? A search has been made with the object of answering this very pertinent question ; but as sulphate of ammonia made its way more by its own intrinsic worth than by the praises of its friends, there is very little specially written on the subject. Perhaps this is not altogether a disadvantage, as one is thrown on the nitrate of soda literature, which has been largely added to by the award of considerable money prizes for essays showing its value as a fertiliser. Such works must necessarily be looked upon as biassed in all that relates to nitrate of soda, but nothing can impair the worth of statements made in them that tell in favour of sulphate of ammonia.

Professor Paul Wagner, Director of the Agricultural Research Station, Darmstadt, in his work on "The Increase of the Produce of the Soil through the Rational Use of Nitrogenous Manures," \* although showing a decided bias for nitrate of soda, gives, in the true scientific spirit, results that must cause astonishment to those lukewarm friends of sulphate of ammonia who, little by little,

\* London : Whittaker, 1888.

are being converted to the belief that nitric nitrogen, as it appears in nitrate of soda, is more effective than ammoniacal nitrogen.

Professor Wagner carried out or initiated during two years tolerably comprehensive experiments on the effect of manuring with ammonia as compared with manuring with nitrate of soda, and gives the result of his researches in a table which shows in the most convincing manner the practically absolute identity of value for the unit in the two forms of nitrogen. He says,\* "In my researches, which were carried out with grass, oats, rye, buckwheat, and rape, usually no considerable difference between the effect of ammonia and that of nitrate showed itself, if the manure was applied in spring, and immediately before the sowing, to a clayey soil which contained a small percentage of carbonate of lime. In several series of experiments, the effect of ammoniacal nitrogen was fully equal to that of nitric nitrogen, as the following examples will show:—

Manure, Nitrogen, per Acre in Lbs.	Yields of Rye.		Yields of Grass.		Yields of Buckwheat.	
	Nitric Nitrogen.	Ammoniacal Nitrogen.	Nitric Nitrogen.	Ammoniacal Nitrogen.	Nitric Nitrogen.	Ammoniacal Nitrogen.
18	43·1	47·4	...	...	35·9	37·2
27	50·0	51·7	...	...	41·8	39·7
36	56·4	55·6	15·0	15·7	45·7	45·6
45	58·1	58·2	17·0	16·9	46·1	48·4
54	62·8	61·6	17·5	18·4	51·8	53·3
63	...	...	18·7	19·3	...	...
72	...	...	20·6	20·8	...	...
0	38·0	...	7·6	...	31·5	...
Average	54·1	54·9	17·8	18·2	42·3	42·8

It may be advisable, in order to prevent any possible misconception, to repeat that  $\frac{1}{2}$  cwt. of sulphate of ammonia is practically equal in nitrogen contents, and consequently in fertilising power, to 1 cwt. of nitrate of soda. It would be in this proportion that the two manures were applied in the various experiments the results of which are given in the table. It has been thought well to plot this table in the form of a diagram, from which the equal intrinsic value of the two kinds

\* *Op. cit.*, p. 63.

of nitrogen can be seen at a glance. Indeed, if any difference be apparent, it is wholly in favour of ammoniacal nitrogen, as, if the character of the curves be considered, the greater regularity of those formed by the results from sulphate of ammonia distinctly prove that this manure is less injuriously affected by adventitious circumstances than is the case with nitrate of soda.

Can any one after this doubt the practically equal efficacy of the same amount of nitrogen whether found present in a manure as nitric acid or as ammonia? No cases of failures can affect the value of such a series of results. All that can be said, if a failure occurs, is that the proper conditions have not been present to make the nitrogen available. Cases in plenty are to be met with where nitrate of soda has not yielded the result that was properly expected from it, and this may also happen with sulphate of ammonia. It would be just as fair to infer from experiments performed under unfavourable conditions that the nitrogen in nitrate of soda is inferior to its value in normal experiments as it is to do this in the case of sulphate of ammonia under similar conditions.

As an example of the extreme unfairness with which facts may be presented so as to injure sulphate of ammonia—possibly without any real intention to do so—the following extract from the work above quoted will show:\*

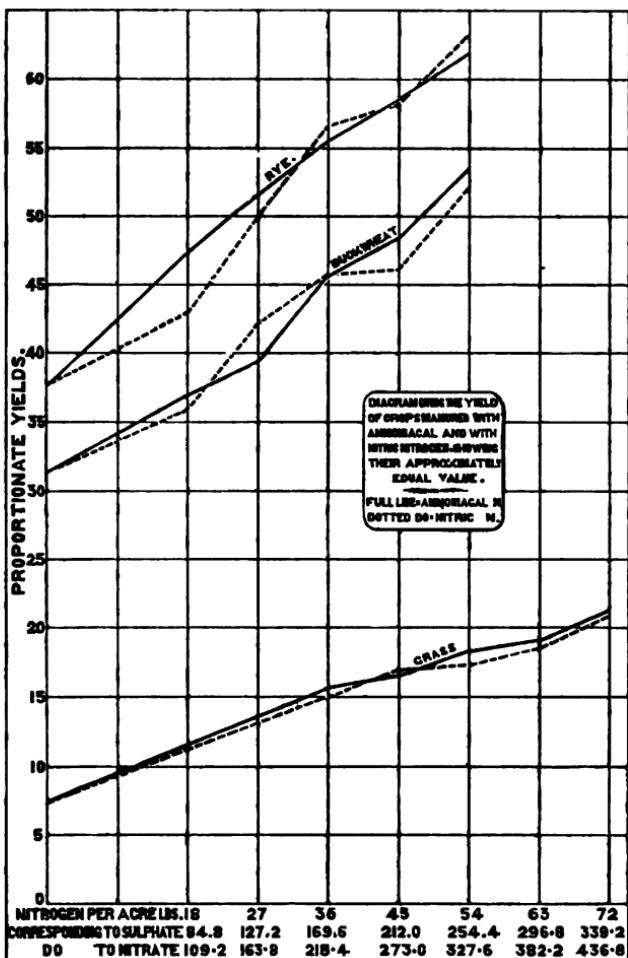
“Some experiments which I carried out with winter rye gave the following numbers as the averages of four closely agreeing parallel experiments.

“Every 10 lbs. of nitrogen as compared with no manure gave the following increase in the crop:—

	Grain. Lbs.	Straw. Lbs.	Grain and Straw. Lbs.
1. No nitrogen in autumn, all the nitrogen given in spring in the form of nitrate of soda . . . .	215	729	954
2. All the nitrogen given in autumn in the form of sulphate of ammonia, no nitrogen in spring . . . .	41	169	210
3. The smaller part of the nitrogen given in autumn in the form of ammonia salt, the larger part in spring as nitrate of soda . . . .	145	575	720
4. The smaller part of the nitrogen given in autumn in the form of nitrate of soda, the larger part in spring, also as nitrate of soda . . . .	156	594	750

\* Wagner, “Nitrogenous Manures,” p. 38.

Of course, it may be answered to the charge of unfairness in the way the above experiments are presented, that they were conducted on the assumption that the nitrogen was equally



effective in whatever form given, and that they really only show that it is simply waste to give it in autumn in any form. That it makes little difference in what form it is administered, Experiments 3 and 4 pretty well prove. Just consider, however, the  
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effect produced on the ordinary reader on instituting a comparison between 1 and 2. The fact that, in the first case, the nitrogen from the nitrate of soda was presented to the plants at the most favourable period, and that the opposite was the case with the sulphate of ammonia, will avail little in the long-run. The majority of readers will simply remember the good effect produced by the nitrate of soda and the failure of the other manure. Nothing better than this example could be adduced to show the crying need for books written in the interest of sulphate of ammonia to distribute amongst farmers. Almost everything that now reaches the gardener and agriculturist is written in the interests of nitrate of soda. So much is this the case, that articles in popular papers are to be found in which the chief chemical manures are described without even mention being made of sulphate of ammonia.

The object of this paper is to direct earnest attention to this anomalous state of affairs in regard to so valuable a by-product, to give reasons why such an unfair condition of things should not continue, and if possible to initiate a discussion that may help to bring about the much-desired improvement. It may, however, be added, that so great has been the benefit rendered by two of the newest industries, namely, the manufacture of basic steel, and the recovery of by-products from blast-furnace gases, to agriculture, the oldest of them all—that with basic slag to be used in autumn and sulphate of ammonia in the spring—the farmer can now provide himself wholly from sources at his very gates with the most necessary ingredients for the cultivation of his crops. As these sources lie within the province of this Institute, it will be the hope of every member that the home-farmer may speedily learn to appreciate benefits that can greatly improve his position, and that can help to bring about that return of prosperity to agriculture so essential to the well-being of the nation.

*CORRESPONDENCE.*

Mr. H. KELWAY BAMBER stated that with regard to the relative values of ammonium sulphate and sodium nitrate, the latter had a more forcing effect on some crops if applied in spring, when active growth was taking place; but all that the plants could not rapidly absorb and make use of was speedily lost by being washed out of the soil by rain and carried away in the drains. Ammonium sulphate had a slower effect, probably from its having first to be converted into nitrates before being taken up by the plants. The surplus not thus used by plants was, however, not lost in a loamy soil, but was held by the loam, and gradually converted into nitrates and rendered available for the future use of plants. Ammonium sulphate had, therefore, a prolonged and more permanent effect on vegetation, whereas sodium nitrate must have an immediate effect or none at all. He had had some fifteen years' personal experience in farming himself, and he had no doubt that ammonium salts had the most beneficial effect on land, whereas sodium nitrate forced most growth, to the detriment of the finer grasses and clovers, and to the injury of the malting property in barley. Sodium nitrate, for these reasons, could only be of use when the plants were in active growth, when they could rapidly make use of it; whereas ammonia salts could be applied to loamy soils at almost any time. Unfortunately, farmers, as a rule, knew nothing of the proper use of these manures, and were dependent on the advice of people from whom they purchased these manures; therefore that substance which was most advertised and pushed got the largest sale very often to the farmer's loss.

Finely ground slag phosphate was perhaps the best form of applying phosphates. Although it was not acid as superphosphate, yet the phosphate of lime was quickly dissolved by rain; the oxide of iron, and lime present also had beneficial effect, and the proper application of finely ground slag phosphate caused clover to appear in land where none was apparent before. Ammonium sulphate and slag phosphate applied to the land at different times (not mixed before putting on the land) made an almost perfect manure, the deficiency being potash salts, which could

be easily and cheaply applied in the form of kainit. The acidity of superphosphate, excepting on land containing lime, in which case the phosphates were converted into precipitated phosphate, which, like slag phosphate, was free from acids, often caused mischief, and probably contributed somewhat to finger-and-toe in turnips. The increased production of ammonium sulphate from blast-furnaces had, of course, brought down the price, as well as that of nitrates, but the relative value of ammonium sulphate was greater than that of sodium nitrate, besides its containing a much larger percentage of nitrogen. Sodium nitrate, to be applied profitably, should be put on in small repeated doses, and when left to a person who knew what he was about, produced considerable increase of crops ; but if used to barley, it injured its malting property. Ironmasters should have those two valuable by-products of their works brought plainly and forcibly before farmers, and their valuable properties concisely stated, for, as a rule, they were most prejudiced and ignorant on these subjects.

Messrs. BRADBURY & HIRSCH (Liverpool), in reference to the relative progress in consumption of nitrate of soda and sulphate of ammonia, repeated what they said in their 1896 "Annual Review" of the sulphate of ammonia market, namely, that sulphate of ammonia producers were labouring under a serious misapprehension in thinking that nitrate of soda had been displacing their product, at any rate, in recent years. Where nitrate of soda had made progress on the Continent, it had been on new ground, where it had been advertised and pushed. On the older ground, and in the United Kingdom, it had barely held its own. It did not seem to be appreciated that within the past six years the world's consumption of nitrate of soda had only increased about 12 per cent., whilst the increase in consumption of sulphate of ammonia in Europe within the same period had been probably 50 per cent. Where sulphate of ammonia had been displaced, it had been displaced by other sulphate of ammonia. Such displacement as there had been in Germany, for instance, had been by sulphate of ammonia produced in Germany and Belgium ; and the wonder was rather that English sulphate of ammonia had so well held its ground. The United Kingdom production within the past ten years had increased something like 80 per cent.

Mr. E. A. BROTHERTON (of Birmingham and Leeds) cordially agreed with the author as to the advisability, indeed imperative necessity, of the publication and distribution broadcast amongst agriculturists, of literature written in the interest of sulphate of ammonia. In preference to essays on the virtues of the product, he would suggest that articles of a lighter character, the great features of which should be pictorial contrasts, would prove more attractive to those whom it was intended to reach, and would in consequence be more effective in making known the character of sulphate of ammonia as a fertiliser. Several articles which had appeared in the popular monthly journals had attracted his attention by the clever manner in which dry statistical facts were represented and by the ingenious methods adopted of showing comparisons. Literature of that character should, he thought, be widely circulated in the agricultural districts.

Professor F. CLOWES, D.Sc. (University College, Nottingham), considered that the author had drawn attention to a very important matter. His conclusions seemed reasonable and well-founded, and were of great interest not only to the ironmaster and gas-maker, but also to the farmer. It was surely important that a home-product, like sulphate of ammonia, should not be neglected in favour of the imported nitrate of soda; especially when the sulphate of ammonia was shown to be weight for weight of greater manurial value than the nitrate, and that its ammonic nitrogen was as effective as the nitric nitrogen of the nitrate. In view of the attempt, already largely successful, to utilise as manure the nitrogen derived from the coal of the blast-furnace in the form of sulphate of ammonia, ironmasters would, he thought, do well to take to heart the author's words, and to make his facts and conclusions widely known. The maker of steel was already contributing to agriculture the valuable phosphatic manure known as basic slag; the value of this was now incontestable. It was interesting to know that another class of manuring agent, containing a wholly different ingredient, was now likely to be furnished in quantity by the iron-smelter who used raw coal wholly or partially in his furnaces.

At the present day experiments such as those made by Paul Wagner were carried out on many experimental agricultural plots,

and the results were made known by County Councils for the good of the farmer. No one was likely to contest Wagner's results, but a repetition and confirmation of them in our agricultural stations in this country would doubtless rouse interest and draw attention to the comparative indifference which was shown towards home-made sulphate of ammonia.

Mr. ROBERT DEMPSTER (Manchester) wished the author's paper had gone farther in the same direction. A good deal more of similar evidence could be adduced. The sulphate trade had been too indifferent, whilst nitrate sellers had never ceased to put forth everything possible in their own favour to show that nitrate was superior to sulphate of ammonia.

If sulphate-makers exercised the same energy as their competitors, and took all available opportunities to show the advantages it possessed on the growth of all crops requiring nitrogenous food, nitrate would not have outstripped sulphate as it had done.

Farmers, either in this country or on the Continent, only required to be informed, by acceptable, simple, and readable literature, of the incontrovertible superiority of sulphate, a given weight containing, as it did, 25 per cent. more nitrogen than the same weight of nitrate of soda, together with the practical and successful result of authoritative trials, to induce them to adopt permanently that, the cheapest and most effective nitrogenous manure.

Mr. JOHN GOLDING (Lecturer on Agricultural Chemistry in the University College, Nottingham) sympathised with the author's plea on behalf of sulphate of ammonia, and agreed with him that, as compared with other nitrogenous manures on the market, its price at the present time was below its real value. At the same time he did not agree with him in supposing that any new name, such as "nitrogenous sulphate," would be likely to remedy this discrepancy, as farmers had too often been imposed upon by vendors of so-called manures, with high-sounding names, but of little or no value in themselves.

The varying results obtained in practical experiments on the comparative value of sulphate of ammonia and nitrate of soda

were very frequently due to the character of the season, as might be well seen by reference to the experiments conducted by Sir John Lawes and Sir Henry Gilbert. Their results showed that in certain years the ammoniacal, and in other years the nitric nitrogen produced the greater crops. It was an old saying with practical farmers that nitrate of soda was suitable for dry weather and sulphate of ammonia for wet, the reason for that being that the soil possessed the power of holding or fixing salts of ammonia, while it exercised no such power on nitrate of soda, which latter would consequently be washed away in a wet season. On the other hand, there was little doubt that nitrates were more easily assimilated by plants than ammoniacal nitrogen. It was also highly probable that the sulphate of ammonia was to a very large extent changed into nitrates by certain bacteria existing in the soil before it was assimilated by plants. Experiments by other scientists had also shown that the period of growth of the plant had not a little to do with the kind of food it required, while with different kinds of plants the one or the other manure might have a preponderance. Those interested in the sale of sulphate of ammonia would do well to emphasise the fact that it could with safety be mixed with superphosphates and other acid manures, while nitrate of soda would suffer loss of nitrogen by such treatment.

He (Mr. Golding) further advocated experiments in the comparative value of these two forms of nitrogen, having special regard to the presence or absence of the micro-organisms existing in the soil. He failed to see the reason why, unit for unit, the sulphate of ammonia should be much cheaper than nitrate of soda, in view of the fact that the former was so easily oxidised to nitrates in the soil by the action of micro-organisms. These points, combined with the fact that the manufacture of sulphate of ammonia was a home industry, should, when known, tend to bring it more into favour with the British farmer, and he therefore supported the author in his advocacy of the publication and free circulation of the advantages to be obtained from the use of this home product.

Mr. JOSEPH HILLMAN (Secretary of the Permanent Nitrate Committee) stated that his committee was quite satisfied to

allow judgment upon the points on which the author joined issue to rest upon the very explicit testimony of recognised authorities on questions of agricultural science and practice.

Mr. T. VAUGHAN HUGHES (Assoc. R.S.M., F.I.C.) stated that in view of the general unsatisfactory state of agriculture in this country, a condition of things largely brought about by a long period of unscientific procedure and neglect, the author's paper was most opportune. As Mr. Carulla had pointed out, the onus of placing that artificial fertiliser in the hands of the farmer would lie mainly with the producer. Indirectly, the Board of Agriculture was charged with assisting the producer of sulphate of ammonia by drawing no distinction between its contained nitrogen and that in nitrate of soda. Like the author, he had been at a loss to find any extended and satisfactory series of experiments which definitely showed a fertilising difference (if any) between artificial manures containing "nitric" nitrogen and those having "ammoniacal" nitrogen in their constitution. To this latter class belonged the artificial fertiliser forming the subject of this paper.

Professor Wagner's results, given by the author, were very instructive. Some large farmers had informed him (Mr. Hughes) that, in their experience, nitrate of soda always gave rise to a *coarse* herbage, particularly on meadow land; so much so that they had discontinued its use. Professor Warrington, in his excellent work on the "Chemistry of the Farm," stated that "nitrate used with cereals gave a larger return in straw than ammonium sulphate." It would be noted that Professor Wagner's experiments proved the yield to be about equal for both "artificials." Hence it would appear that the quality of a crop was affected by nitrate of soda. It would seem needful that further well-planned field experiments should be instituted to definitely settle that question, and especially in view of Dr. Voelcker's and other researches on the assimilation of nitrogen by plants. Again, it might be that the physical property of ammonium salts of being tenaciously held by the soil would make its more extended use by the farmer a matter of economy, particularly during wet seasons. Granted that the object of the paper might be speedily attained, it was to be hoped that the

makers of ammonium sulphate would exercise the greatest care, and prevent the placing on the market of a fertiliser containing ingredients highly deleterious to plant life, such as sulphoncyanide of ammonium. Further, it would be well if the sellers bartered their salt on the basis of its nitrogen content, and insisted that its *worth should be computed on the "units of contained nitrogen."* Any harmful substances incorporated with it, or adulterants likely to render it useless as a fertiliser, should cause its rejection. Sufficient stress could not be laid upon these points. Sales effected under the provisions of the Fertiliser and Feeding Stuffs Act would ensure confidence in buyers. Let it be remembered that one season's bad result, following the application of a parcel of ammonium sulphate containing substances harmful to plant life on a farm, would ruin the prospects of the more extended use of this artificial manure by the British agriculturist for years to come.

**Mr. EDWARD JACKSON** (H.M. Inspector under the Alkali Acts) thought that the main point the author had brought out in the paper—relative prices of ammonium sulphate and nitrate of soda, showing depreciation of the former—was doubtless due to a combination of circumstances, most of which had been referred to in previous discussions on the subject. Probably, however, one of the main difficulties was with the farmers, who were most conservative in all matters, and might have some prejudice as to any products from so-called “chemical works.” Nitrate in their eyes did not labour under this disadvantage. Possibly change of name might result in an improved demand for ammonium sulphate for agricultural purposes.

**Mr. J. F. KEMPSON** (Pye Bridge), while agreeing generally with the author, thought that, to meet the problem before them, it was necessary to go further than popularising the use of sulphate of ammonia for agricultural purposes, at least as such were carried on in Great Britain. The recovery of nitrogen from coal, shale, &c., was not only enormous, but was capable of great expansion on any rise in values. That pointed to the wisdom of those who were interested in nitrogen recovery looking to new developments in its application. In approaching that part of the subject, they should

regard conditions which, though anomalous, might be frequently found side by side. He alluded to such matters as cheap materials, unemployed labour, undeveloped land, cheap water-carriage, deposits which must be removed even at a dead expense, &c. For present purposes, these conditions could all be more or less found in the districts of the Clyde, Tyne, Tees, Mersey, and South Wales. There was an immense area of rocky land easily accessible by water-carriage, the soil on which was only a few inches deep, that was commonly regarded as useless for cultivation. That was too easily taken as inevitable with such fertilisers as sulphate of ammonia and basic phosphatic slag were produced cheaply in close proximity. By the free use of artificial manures and judicious culture a productive soil might be created. To deepen the soil on rock, sewage sludge could be used, and might be mixed with sandy dredgings, which had to be raised, but were simply taken out to sea. In the case of sewage sludge from lime precipitation, it would be necessary to modify the treatment as to the application of sulphate of ammonia. Coming to the labour of reclaiming rocky land in this way, there was a supply of that great desideratum, unskilled labour, of a non-competitive kind for the poor-law authorities and those dealing with the unemployed.

Another direction in which sulphate of ammonia and basic slag might find application was in the English production of beet sugar. That had been proved to be possible on a manufacturing scale, but the enterprise was discontinued owing to the uncertain supply of beets. He thought it spoke badly for English intelligence and enterprise that sulphate of ammonia had to go abroad, and that when the value of basic slag was first demonstrated the rush to get that cheapest source of phosphorus for agriculture was from foreigners.

MR. FRANK LIVESEY (of the South Metropolitan Gas Company) considered the points raised by the author were of great importance, not only to the members of the Iron and Steel Institute, but also to gas managers generally. The chief question raised was, Why should the nitrogen in sulphate of ammonia be of less value than in nitrate of soda? With that point the author had dealt fully, though perhaps he might have added that sulphate was a far superior salt for mixing with other fertilisers than

nitrate; indeed, it was a question whether it could be mixed at all except by the farmer on the ground, the deliquescent properties of nitrate being the trouble.

Was not the low price of sulphate due in a very large measure to the way in which it was commercially handled? Under the existing state of things the producer was inaccessible to the consumer, owing perhaps to some condition of sale; the dealer who intervened was consequently very powerful, and being a speculator, naturally forced variations in price to his own interest. This militated against sulphate of ammonia, as the consumer was never sure of the price he might have to pay. The managers of gas undertakings, and possibly of iron and steel works also, were not in a position to watch the market, and could not expect, therefore, to be successful speculators; inasmuch also, as sulphate was not produced in accordance with the demand, but in accordance with the demands for other products, it was not a wise policy to stock this material to any great extent. The author stated that all the fertilising qualities the farmer required could be obtained from basic slag and sulphate of ammonia. Would it not be wiser to recommend sulphate, because it could be mixed, and so more nearly approach the complex nature of a perfect manure? That, as already explained, could not be done with nitrate. The Sulphate of Ammonia Committee that had been formed might do some useful work by bringing before farmers the value of sulphate as a fertiliser, and by explaining where and when it was superior to nitrate. That to some extent was a matter of climate or atmospheric conditions. Sulphate of ammonia was, he thought, so well known that it seemed quite unnecessary to change its name. It would in his opinion do more harm than good.

Colonel S. A. SADLER (Mayor of Middlesbrough) considered that the subject brought forward by the author was one of deep interest to ironmasters and to chemical manufacturers, for latterly ironmasters had to look to the residual products for their profit. In Scotland the by-products were obtained from the blast-furnace. In Westphalia, and to a considerable extent in the North of England, they were obtained from the coke-ovens. Recently Dr. Ludwig Mond had gone a step further by devising a method of

recovery of ammonium sulphate from producer-gas. The ingenious arrangement employed was fully described in the *Journal*, 1896, No. I. p. 144. The advent of large quantities of ammonium sulphate from those sources had been so sudden and unexpected, that it probably had much to do with the collapse that had taken place in its value. More and more sulphate would, he thought, be put on the market by iron and coke makers no matter to what the price might be reduced, so long as it would pay to recover it, say £5 per ton. Undoubtedly the chief cause of the abnormal position of sulphate in relation to nitrate of soda was mainly the large inducements that the Nitrate Committee had offered, to advertise nitrate. Nothing of the sort had hitherto been done by sulphate producers. A powerful organisation of sulphate manufacturers was, however, in course of formation, and it was to be hoped that that would tend to remove the apathy that had hitherto existed. The physical superiority of sulphate over nitrate for agriculture should not be overlooked. Sulphate was a friable efflorescent salt easily mixed and handled, whilst nitrate was deliquescent, and always exhibited a tendency to cake. Moreover, the much greater solubility of nitrate as compared with sulphate was a serious drawback to its application in wet climates.

Mr. JAMES O'SULLIVAN (Burton-on-Trent) thought that the case of sulphate of ammonia against nitrate of soda had been stated in a very clear and convincing manner. He felt certain that the unit of nitrogen in the nitrate was of no more value than it was in sulphate of ammonia. Advertisements of nitrate which were continually put in the hands of the farmer had, he considered, more to do with its sale than its composition.

Mr. CHARLES TAYLOR (of the Gas Works, Derby) said it appeared to him perfectly clear that the "booming" of nitrate of soda had placed it in a position to which it was not intrinsically entitled, and that sulphate of ammonia was generally the cheaper article at from £2 to £3 per ton more money. The remedy for the evil and misconception in regard to the use of sulphate of ammonia was, he thought, to be found in advertising and in collecting the already well-written literature

on the subject, adding thereto tabulated expert information upon the application of sulphate of ammonia under the various conditions affecting particular localities, so that the farmer would not be called upon to treat his soils with indefinite knowledge as to their requirements. Much might be said in favour of changing the name to that of "nitrogenous sulphate," and the change was fully justified by the fact of its containing, weight for weight, about 25 per cent. more nitrogen than is contained in nitrate of soda.

**Mr. CARULLA** wrote in reply: It is quite true, as Mr. Dempster points out, that more evidence similar to that given in the paper might be adduced. In one of the prize-essays, to which Colonel Sadler alludes, for example (*Nitrate of Soda: A Prize-Essay by A. Stutzer, Ph.D. London: Whittaker & Co., 1887*), it is stated on page 93 that the crop gained by the use of every 1 cwt. of nitrate of soda exceeded on an average by 180 lbs. that derived from the corresponding quantity of sulphate of ammonia ( $\frac{3}{4}$  cwt.) when the manures were applied to potatoes. On examining into this statement, it is found that this is the average of thirty-six experiments given on pages 83 and 84, which list consists of forty experiments. Four experiments are thus left out, and two of these are so remarkable as to show an advantage for sulphate of ammonia of 1430 and 1925 lbs. respectively! The majority of readers only turn to the summaries, and few will investigate how the figures are obtained. Such cases, proving the necessity for a special sulphate of ammonia literature, might be largely multiplied, but more of them were not given in the paper, as it was intended merely as a framework round which it was hoped a good discussion might grow, remembering that "in the multitude of counsellors there is safety."

The point so prominently brought out by Messrs. Bradbury and Hirsch is apt to be overlooked. The sulphate of ammonia producers are not only harassed by the nitrate of soda interest, but they are in a state of civil war amongst themselves. In such circumstances it is quite possible to overrate the harm done by nitrate of soda, but none the less the need for concerted action remains. Colonel Sadler also fully proves this, and it must be

repeated that nothing except a special literature and plentiful advertising seems likely to be able to bring back prosperity to this home industry. Mr. Brotherton's suggestion is excellent; pictures will influence the average man more than figures. The institution of local experiments, as recommended by Dr. Clowes and others, is also a matter that deserves attention, as farmers are more likely to be impressed by results obtained in their immediate neighbourhood than by reports of performances in other countries, where both climate and soil may be different from their own. Mr. Taylor is right in saying that there is already good literature. Yes, for the manufacturer! but not such as can with advantage be put into the hands of the consumer. For instance, such information as Mr. Vaughan Hughes gives in this discussion about sulphocyanides is totally out of place in a pamphlet intended for the farmer, who will only be repelled instead of attracted by such statements, right as it is to impress them on the manufacturer. Before distributing any of the pamphlets now offered for circulation, sulphate-makers should read them themselves, and be as cautious as those mothers who peruse the novels intended for their daughters. No fear of the nitrate-producers falling into such a mistake, and, for instance, distributing literature to show that the presence of perchlorate in nitrate of soda has been the cause of injury to crops.\* In this connection it may be useful to mention that the danger of getting sulphocyanides into sulphate is practically a matter only of historical interest. The danger was a very real one so long as the manufacture was conducted by direct saturation of the gas liquor, but now that the ammonia is almost universally driven off in plate stills, the danger no longer exists.

Mr. Frank Livesey rightly says that nitrogenous and phosphatic manures are not the only requisites for the growth of crops. Lime is largely present in basic slag, but potash, which is also essential, can only be economically obtained from such sources as kainit. The paper was not intended to convey so erroneous an impression as that nitrogenous and phosphatic manures are the only essentials. Mr. Livesey objects to the suggested change of name, as does Mr. Golding, and it may be that a middle course would be the best. The scientific term ammonium sulphate, used

\* *Journal of the Society of Chemical Industry*, vol. xvi. p. 342.

by some of the writers, also places the idea of sulphate secondary, and it might be well to adopt it for common use; the impression of "chemical works," mentioned by Mr. Jackson, not being conveyed so forcibly as by the present name.

Possibly Mr. Kempson's suggestion might be of value in particular localities, but where good land is already going out of cultivation, there could be no advantage in attempting to reclaim the wastes. The statement of the money paid away by this country for sugar that might be produced by ourselves goes some way to confirm the calculation given in Mr. Truchot's work *L'Ammoniaque*, that England only consumes one-sixty-sixth of the nitrogenous manures that could be used with advantage. There is therefore plenty of inducement and justification for the various sections of ammonium sulphate makers to work amicably together, with the single aim in view of spreading the knowledge of the intrinsic value of their product amongst home-farmers.

NOTE ON THE  
SPECIFIC HEAT OF IRON AT HIGH  
TEMPERATURES.

BY PROFESSOR W. N. HARTLEY, F.R.S., ROYAL COLLEGE OF SCIENCE, DUBLIN.

IN a paper which I had the honour of contributing to the Proceedings of the Iron and Steel Institute,\* it was stated that the specific heat of molten iron and of gaseous compounds at high temperatures were values which were wanting for the completion of thermo-chemical calculations.

The specific heat of iron as determined by Regnault (0·11379) and confirmed by Pionchon † approached very nearly the number given by Joannis ‡ (0·1138), which led to this number being adopted. Mr. C. H. Ridsdale pointed out the difference between this figure and that employed by Sir Lowthian Bell for steel, viz., 0·245; but this value, it was admitted, was not satisfactory at high temperatures. § It was evident that there were difficulties surrounding the subject, from the researches of Weber, || on the specific heat of carbon and silicon, and from those of Viole on the specific heat of platinum.¶

In Mendeleëf's "Principles of Chemistry," \*\* it is stated that Byström †† found the specific heat of iron to be represented by the following numbers:—At 0° C. = 0·1116; at 100° C. = 0·1114; at 200° C. = 0·1118; at 300° C. = 0·1267; at 1400° C. = 0·4031. There is a long interval between the two last temperatures, but the final figure, namely 0·4031, is much higher than that given by other investigators, and hence there is some doubt of its being quite correct. A series of papers giving the results of researches

\* *Journal*, 1895, No. II. p. 28.

† *Comptes Rendus de l'Académie des Sciences*, vol. cii. p. 677, 1886.

‡ *Le fer et ses compost.* Fremy's *Encyclopédie Chimique*, p. 5.

§ "Manufacture of Iron and Steel," p. 423, 1884.

|| *Pogg. Ann.*, vol. cliv. p. 490, 1875.

¶ *Comptes Rendus*, p. 543, 1877; p. 981, 1878; and p. 702, 1879.

\*\* Vol. i. p. 575, 1891.

†† I have been unable to consult Byström's paper.

on the specific heats of metals, including iron, are those of Mr. Pionchon, which appear to be the most recent and of the first importance in this connection, namely, *Sur l'Étude Calorimétrique des Métaux aux Hautes Températures.*\* I have thought that the subject may be of sufficient interest to justify the publication of a short note on the subject. The specific heat of iron increases at high temperatures in so remarkable a degree as to indicate a change in its molecular condition. From 0° C. to 660° C. the formula for the specific heat,  $\gamma$ , at temperature  $t$ , is,

$$\gamma t = 0.1012 + 0.0000506666t + 0.000000163998t^2.$$

From 1050° to 1200°,

$$\gamma t = 0.1987;$$

or, to quote the average specific heats,

$$\begin{aligned} \text{From } 750^\circ \text{ to } 1000^\circ \text{ C.} &= 0.213 \\ 954^\circ \text{ to } 1006^\circ \text{ C.} &= 0.218 \\ 1050^\circ \text{ to } 1200^\circ \text{ C.} &= 0.19887. \end{aligned}$$

The change in the molecular condition of the metal is indicated by the rise in the specific heat from the value 0.1137 to 0.218, up to 1000°, and its decrease afterwards. The last figure quoted above, namely, 0.19887, is the one which chiefly concerns the thermo-chemical calculations with which we have to deal in molten Bessemer metal or pig iron, but the results are widely different from those of Byström.

Pionchon has pointed out that the law of atomic heat (Dulong and Petit) is seriously affected, so that if the atomic weight of iron be deduced from the highest value for the specific heat which he recorded, it is necessary to assume that iron has an atomic weight at high temperatures of about 1000°, which is only one-half of that under ordinary conditions, viz., 28 instead of 56; thus:  $0.218 \times 28 = 6.104$  atomic heat. In other words, the law of Dulong and Petit holds good only for metals at temperatures between 0° and 100° C.

Even then, as Mendeleëf points out, there is a divergence from this law if the substances have low atomic weights, as lithium = 7, glucinum = 9.2, among metals, as well as carbon = 12, boron = 11, and silicon = 28, among non-metallic elements.

\* *Comptes Rendus*, vol. cii. p. 675, and p. 1457, 1886; also vol. cihi. p. 1122, 1887.  
1897.—i.

As regards the specific heat of gases, it has been shown that they increase with rise of temperature if they are not elementary substances. According to the experiments of Regnault and Wiedemann, the specific heat of  $\text{CO}_2$  at  $0^\circ = 0.19$ , at  $100^\circ = 0.22$ , and at  $200^\circ = 0.24$ ; but for CO we have no figures at all available. There can be little doubt that as a compound gas rises towards the temperature when dissociation commences, the specific heat undergoes a change. Hence, in these circumstances, we see how difficult it is to determine by calculation even approximately the temperature of the metal and of the gases which by their chemical action with the oxygen of the air contribute to the phenomena of the Bessemer "blow."

Nevertheless a recalculation based on the specific heat of iron = 0.19887 at  $1200^\circ \text{ C.}$ , shows that the temperature attained in the acid process is  $1057^\circ$  above this, or  $2257^\circ$ ; but on the supposition that as much as one-half the available heat is lost, the temperature cannot be less than  $1728^\circ \text{ C.}$

*RECEPTION BY SIR DAVID AND  
LADY DALE.*

On Monday evening, May 10th, the retiring President and Lady Dale hospitably entertained the members and ladies accompanying them at a reception at the Royal Institute of Painters in Water Colours, Piccadilly. It was attended by about six hundred ladies and gentlemen.

*THE ANNUAL DINNER.*

The members of the Institute dined together in the Grand Hall of the Hotel Cecil on Tuesday evening, the 11th May, when covers were laid for two hundred and seventy. The chair was occupied by the President, Mr. Edward P. Martin, who was supported by a number of distinguished guests, and by most of the members of Council. Amongst those who accepted invitations were His Highness the Duke of Teck, G.C.B., the Honourable Alexander Hood, Comptroller of the Household of H.R.H. the Duchess of Teck (in attendance on the Duke of Teck), Sir Courtenay Boyle, K.C.B. (Permanent Secretary to the Board of Trade), Sir Andrew Noble, K.C.B., Sir William Anderson, K.C.B., Sir John Evans, K.C.B., Treas. R.S., Sir John J. Jenkins, M.P., Sir Henry Mance, C.I.E., General Markham, Admiral Bowden-Smith, Mr. J. Wolff Barry, C.B. (President of the Institution of Civil Engineers), Mr. Windsor Richards (President of the Institution of Mechanical Engineers), General Lloyd, C.B., Admiral Douglas, Professor Norman Lockyer, C.B., F.R.S., Mr. A. E. Bateman, C.M.G. (President of the Royal Statistical Society), Professor Ayrton, F.R.S., Professor Dewar, F.R.S., the Master of the Cutlers' Company, the Master of the Armourers and Braziers'

Company, the Deputy-Master of the Needlemakers' Company, Mr. H. W. Martin (President of the South Wales Institute of Engineers), the Worshipful the Mayor of Cardiff, the Town-Clerk of Cardiff, Mr. T. Hurry Riches (Hon. Local Secretary for the Cardiff meeting), and Dr. J. H. T. Tudsbery (Secretary of the Institution of Civil Engineers).

The toast of "The Queen" was proposed by the President in the warmest terms, and was received with most enthusiastic loyalty.

The toast of "The Prince and Princess of Wales, and the other Members of the Royal Family," proposed by the President, was acknowledged by the Duke of Teck.

Sir Edward Carbutt, Bart., proposed the "Navy, Army, and Auxiliary Forces." Admiral Bowden-Smith responded on behalf of the navy, and General Markham on behalf of the army.

Sir David Dale, Bart., Past-President, then proposed "The Houses of Parliament," and coupled with the toast the name of Sir John J. Jenkyns, who responded.

Professor W. C. Roberts-Austen, C.B., Member of Council, next proposed the toast of "Kindred Societies," coupling with it the names of Sir John Evans, K.C.B., Treasurer of the Royal Society, and Mr. J. Wolff Barry, C.B., President of the Institution of Civil Engineers, both of whom responded.

The Right Hon. Sir Bernhard Samuelson, Bart., Past-President, proposed "Our Guests," and coupled with it the names of the Mayor of Cardiff, Sir Henry Mance, and the Master of the Cutlers' Company, all of whom replied.

Sir Courtenay Boyle, K.C.B., proposed "Prosperity to the Iron and Steel Institute," a toast which was acknowledged by the President, and the proceedings terminated.

*OBITUARY.*

**CHARLES ALGER** died at Hudson, New York, on January 2, 1897. He entered business with his father at the Hudson Iron Works, after which he went to the West Point Foundry, and thence to Maryland. He afterwards took charge of the Albany Foundry, from which position he retired in 1877. He was elected a member of the Iron and Steel Institute in 1880.

**THOMAS BARBOUR** died at Workington on November 17, 1896, at the age of fifty-nine years. He was manager of the Derwent Works of Messrs. Cammell & Co. for many years, and on the reconstruction of the Derwent Works was appointed managing director. He was a Justice of the Peace for the county of Cumberland, and was elected a member of the Iron and Steel Institute in 1880.

**FRANCIS THOMAS BARNETT**, who died at Buluwayo, British South Africa, in 1896, received his technical education at the Royal School of Mines, graduating as Associate of the Royal School of Mines in 1882. In 1884 he was appointed chemist and steelworks manager to Messrs. Hatton Sons & Co. of Birmingham, and in 1894 he was appointed representative for F. Siemens, Esq., in the Midlands, North of England, and Scotland. In 1896 he was appointed chemist and assayer to the Belingwe Consolidated Gold Mines, Buluwayo. He was a Fellow of the Chemical Society, and was elected a member of the Iron and Steel Institute in 1883.

**WILLIAM BUTLIN**, of Duston House, near Northampton, died at Weymouth on February 4, 1897, at the age of seventy-three years. He was educated at the Guilsborough Grammar School, and on leaving school became a pupil in the firm of Berry & Co., machine engineers, Liverpool, and afterwards studied at the College of Civil Engineers, Putney, where he gained his full certificate as a civil engineer in 1848. Mr. Butlin started the old Vulcan Works, Weston Street, Northampton, for the manufacture of steam-ploughs, portable engines, agricultural

machinery, &c. This business he carried on with great success for upwards of twenty years. He made the first leather-splitting machine used in Northampton. He took a leading part in founding the iron ore industry in Northamptonshire. He was an exhibitor at the Exhibition of 1851, and there saw some specimens of Northamptonshire iron ore; and on finding that deposits of this mineral abounded on his family property, he at once set to work to make a series of experiments at the Vulcan Works. He is said to have smelted the first piece of iron in his county, and this specimen had a place in the Northampton Museum for some time. In 1852 the East End Iron Works were established at Wellingborough, the one furnace there built being afterwards replaced by two. In 1866 the business of the firm had so increased as to render it necessary to build the Irthlingborough Works at Wellingborough. Mr. Butlin did not take any active part in politics, but identified himself with all local movements. He was elected a member of the Iron and Steel Institute in 1882.

ALEXANDER MILNE DUNLOP died at 11 Norfolk Street, Park Lane, London, on January 5, 1897. He was educated at the High School, Glasgow, and commenced his professional career in the office of Mr. Peter MacBey of Elgin, estate agent and surveyor. He afterwards entered the London office of Mr. H. E. Marsh as surveyor. After carrying out important and extensive surveys in Africa, he returned to London and commenced business in Victoria Street, Westminster, afterwards removing to Old Palace Yard. He visited the United States and Canada, and travelled throughout Europe on business connected with agricultural and mining properties. His most important work was the conduct of the whole of the valuations and negotiations in connection with the Manchester Ship Canal, and the new line of the Manchester, Sheffield, and Lincolnshire Railway. He was also largely engaged in various arbitration cases in connection with the great railway companies. He was one of the surveyors to the Board of Trade and to the Charity Commissioners, and was managing director of the Oakeley Slate Quarries at Festiniog. He was an Associate of the Institution of Civil Engineers, and a Vice-President of the Surveyors' Institution. He was elected a member of the Iron and Steel Institute in 1888.

WILLIAM FARNWORTH died at his residence, the Manor House, Sedgley, on January 14, 1897, at the age of sixty-nine years. He was

for many years manager of the works of Messrs. Baldwin & Sons, of Swindon, where he was recognised as an authority on the manufacture of iron and steel. He was the author of several papers read before the Iron and Steel Works Managers' Association of South Staffordshire, of which he was a prominent member. He was a Fellow of the Geological Society, and, as a geologist familiar with the geology of the district, he was frequently consulted on mining matters. He was Vice-Chairman of the Seisden Board of Guardians, and took an active interest in the municipal and social life of both Swindon and Sedgley. He was made a Justice of the Peace for the county of Staffordshire a short time before his death. He was an original member of the Iron and Steel Institute.

JOHN GALLOWAY died at Seymour Grove, Old Trafford, on December 16, 1896. Born in 1825, he was early associated with his father's profession of engineering. He continued to take an active part in the management and development of the Knott Mill Iron Works until that concern was turned into a limited liability company a few years ago. He did not take an active part in politics, but was intimately associated with many social and philanthropic movements, and was a Justice of the Peace for the city of Manchester and for the Hundred of Salford. He was President of the South-West Manchester Conservative Association from the formation of that division, of which his son is the present representative in Parliament. Mr. Galloway was elected a member of the Iron and Steel Institute in 1875.

ISAAC JAMES JENKS died at his residence, Glen Tower, Wolverhampton, on March 4, 1897, at the age of fifty-two years. He was the son of the late John Jenks, and was born at Sunderland in 1845. After spending some years with his father at the Minerva Iron Works, the property of his uncle, he joined his father in partnership in the Cleveland Iron Works, Wolverhampton, of which, on the death of his father, he became sole proprietor. He was a Justice of the Peace, and took an active part in the municipal affairs of Wolverhampton, where he was much respected both for his business capacity and for his genial character. He was elected a member of the Iron and Steel Institute in 1885.

BENJAMIN MARDEN died on January 30, 1897. He was the principal of S. Marsden & Sons, Limited. He was well known throughout

the iron trade of Lancashire, and had been closely identified with the trade for nearly fifty years, the works, which were established by his father in 1845, having been practically under the control of Mr. Benjamin Marsden for the last thirty years, and under his management they have been steadily developed, until they are by far the largest works of their kind in Lancashire, giving employment to about four hundred hands, and fitted with all the most modern plant and machinery—a large portion being of their own special design and construction. Mr. Marsden recently paid two visits to the United States in order to make himself acquainted with the best American improvements in his particular line of trade; and one special result was the introduction of oil furnaces for heating the bar iron used in the manufacture of bolts, a complete plant of which has been for some time in operation at the Manchester works, whilst the firm have also manufactured and sold a large number of these furnaces to other works in the trade.

Mr. Marsden was a member of the Institution of Mechanical Engineers and of the Manchester Association of Engineers, and was closely identified with all the trade interests of the district. He was elected a member of the Iron and Steel Institute in 1887.

HENRY FELL PEASE, of Brinkburn, Darlington, died on December 6, 1896, at the age of fifty-nine. He was a director of the firm of Pease & Partners, of Darlington; chairman of the Tees Side Iron and Engine Works Company up to the date of its amalgamation with the firm of Sir Christopher Furness, Westgarth & Co., when he became a director of that company. He was also intimately connected with various other undertakings, and was part owner of the cotton-mills of Henry Pease & Co.'s Successors. He was member of Parliament for the Cleveland division of Yorkshire from 1885, and Deputy-Lieutenant and Justice of the Peace for the North Riding of Yorkshire. He had been Mayor of Darlington, and always took an active interest in the social and political life of the various districts with which he was connected. He was elected a member of the Iron and Steel Institute in 1882.

JOHN RAMSBOTTOM died at Alderley Edge, Cheshire, on May 21, 1897, at the age of eighty-three. He was one of the best known and ablest men connected with the early history of locomotive, general mechanical, and metallurgical engineering during the present century. He was for many years chief mechanical engineer of the London and

North-Western Railway, and was succeeded in that position by Mr. F. W. Webb. He took the lead in the laying out of the railway town of Crewe and the extensive works there. Under his direction the Bessemer and open-hearth processes of steel manufacture were adopted at Crewe. He was also the originator of the Ramsbottom system of rail and cogging mills. He did much to advance the practice of engineering generally, but especially in reference to locomotive and fixed engines, and he also invented the system of taking up water by locomotives running at full speed. He retired from the service of the London and North-Western Railway in 1871 on account of ill-health, but afterwards took an active part in the management of the Lancashire and Yorkshire Railway, of which, on the death of Lord Houghton, he was elected a director. He was for many years a prominent member of the Institution of Mechanical Engineers, of which he was President in 1870. He received the degree of Master of Engineering from Dublin University, and was a governor of Owens College, Manchester. He was also a member of the Institution of Civil Engineers, and an original member of the Iron and Steel Institute, and was elected Vice-President at the first general meeting of the members on February 25, 1869.

RICHARD CHRISTOPHER RAPIER died at Folkestone on May 28, 1897, at the age of sixty-one years. He was educated at Christ's Hospital, London, and on leaving school was apprenticed to the firm of Robert Stephenson & Co., locomotive engineers, Newcastle-upon-Tyne, where he was afterwards appointed an assistant. He subsequently entered the Orwell Works of Messrs. Ransomes at Ipswich, and afterwards became the London representative of that firm, in which he was so successful that new works had to be constructed at Ipswich for the special manufacture of railway plant and materials. Mr. Rapier was managing director of these works at the time of his death. He took a leading part in the construction, in 1875, of the first Chinese railway, which, however, was dismantled soon after by natives, who purchased it for that purpose. He was the author of a paper read before the Institution of Civil Engineers on dividing the traffic on railways into fast and slow, for which paper he was awarded the Salford Medal by the Institution. He was connected with various important enterprises, and was a member of the Institution of Civil Engineers, the Institution of Mechanical Engineers, the Geological Society, and other scientific and technical societies. He was elected a member of the Iron and Steel Institute in 1874.

HENRI RÉMAURY died at Paris on June 15, 1897. Born at Mirepoix, in Ariège, in 1833, he entered the Paris School of Mines in 1854. Shortly after graduating at that school he was appointed engineer with Messrs. Dupont & Dreyfus at their important works at Ars, on the Moselle, where he distinguished himself by the splendid results which he obtained in exploring for mineral deposits, as well as in his metallurgical work. He was soon after appointed director of the works. While engaged in these works on the French frontier he was taken prisoner by the Germans during the war of 1870. As a result of the war, the works at Ars, on the Moselle, being situated in the annexed territory, were given up to a foreign company. Mr. Rémaury therefore built entirely new works for the firm of Dupont & Dreyfus at Pompey. He subsequently established himself in Paris, and was for some time engaged as consulting engineer to the Crédit Lyonnais, where he was employed in several highly important undertakings, notably in the formation of the Villerupt Works. Among the other important works in which he took a share may be mentioned the opening of collieries at Kébaò in Tonkin, and the amalgamation of the Decazeville Works with those of Fourchambault. He was one of the founders of the valuable French technical journal *Le Génie Civil*, and acted for some years as chairman of the publication committee of that journal. In 1890 he was awarded the annual prize by the Society of Civil Engineers of France for an important paper on the Mineral and Metallurgical Resources of Meurthe-et-Moselle. He was a Knight of the Legion of Honour, and acted as member of the jury at the Paris International Exhibition of 1889, and at several other exhibitions. Quite recently he was appointed member of the Public Works Committee of the French Colonial Office. He was elected a member of the Iron and Steel Institute in 1880.

PETER VON TUNNER died at Leoben, in Styria, on June 8, 1897. Born on May 10, 1809, at Turrach, in Styria, he was from his youth up occupied with mining and smelting. He obtained his scientific training at the Vienna Polytechnic. On the completion of his studies he worked for two years in the steelworks of Prince Schwarzenberg, where, after some practical experience in other works, he received a permanent appointment. He had thus early acquired not only a good theoretical education, but also a varied practical training, and was consequently eminently suitable for the post of Professor of Metallurgy in the new Joanneum at Graz. The Archduke John selected Tunner

for this appointment, and travelled in 1833 to Katsch in order to arrange terms with him personally. The great interest the Archduke took in his protégé is shown in a letter dated September 14, 1833, which is to the following effect: \* "After careful investigation I recommend for the appointment Peter Tunner. A native of the district, of best moral character, one of the best students of the Polytechnic Institute, thoroughly furnished with the requisite scientific knowledge, experienced in the local treatment of iron, of good presence, he fulfils all the requirements of the post." Two years later Tunner received the appointment as Professor. He was only twenty-six years of age when he was nominated. In March 1837 he began an educational journey through the mining and metallurgical districts of Austria, Hungary, Germany, Sweden, England, France, Belgium, and Italy. On November 4, 1840, the new mining school at Vordernberg was inaugurated, and here Tunner instructed the students in practical metallurgical work. In 1849 the institution was moved to Leoben, and on October 14, 1861, it was converted into a mining academy. How completely Tunner's whole existence was wrapped up in this institution that he founded, whose fame extended far beyond the frontiers of the Austrian monarchy, is well shown by a remark he once made. "When," he said, "my last hour comes, I do not know whether I shall think more of my family or of my academy." The work begun in 1840 by Tunner as lecturer on the metallurgy of iron, and continued with astonishing energy for a lifetime, was the foundation of scientific metallurgy. His last course of lectures on the metallurgy of iron was delivered in 1865-66. On July 20, 1874, he retired from active work.

As Professor, he gave full attention to all inventions and improvements in connection with iron and steel. He was one of the first to appreciate the importance of the Bessemer process, and its introduction into Austria was due to his energy. As an author he was continually active. His numerous memoirs were published chiefly in the Leoben Mining and Metallurgical Yearbook, and in the Transactions of the Vienna Geological Survey. He also wrote treatises on the calibration of rolls, on the future of the Austrian iron trade, on the mining industry of Russia, and a report on the London International Exhibition. One of his last monographs was an excellent account of the iron industry of Styria and Carinthia, prepared on the occasion of the visit of the Iron and Steel Institute to Austria-Hungary in 1884. Since 1845 he visited all the great exhibitions, and

\* *Stahl und Eisen*, vol. xvii. p. 521.

even at the age of sixty-nine faced the fatigues of a journey to America to take part in the Centennial Exhibition. In 1867 he was elected a member of the Styrian Parliament, and in the same year was elected to the Imperial Parliament. Honours were showered upon him. In 1864 he was knighted by the Emperor, and he had conferred on him at different times the crosses of numerous orders of chivalry, including the Austrian Franz-Josef Order, the Austrian Iron Crown, the Prussian Crown, the Russian Stanislaus Order, the Swedish Order of Vasa, the Friedrich Order of Wurtemberg, the Albrecht Order of Saxony, and the Michael Order of Bavaria. He also received the honorary freedom of the towns of Leoben, Vordernberg, Eisenerz, Hüttenberg, Bleiberg, and Raibl, and was an honorary member of the Society of German Iron Metallurgists, of the American Institute of Mining Engineers, of the Philosophical Society of Philadelphia, of the Royal Academy of Sciences of Stockholm, and of the Academy of Sciences of New York.

He was elected an honorary member of the Iron and Steel Institute in 1875, and in 1878 received the Bessemer Gold Medal. He communicated three papers to the Institute: one in 1873 on the value of superheated blast in the working of blast-furnaces; and two in 1882 on the iron industry of Styria and Carinthia, and on the use of lignite or brown coal in the blast-furnace.

CHARLES CLEMENT WALKER died at his residence, Lilleshall Old Hall, on February 4, 1897, at the age of seventy-five years. He was the head of the firm of C. & W. Walker, of Donnington, Shropshire, which was established in 1858. The business rapidly increased and developed until it was, at the time of Mr. Walker's death, probably the largest of its kind in the world, and the works covered an area of over twenty acres. As gas works manufacturing engineers, the firm of Messrs. Walker had connections all over the world. Mr. Walker was well known and greatly respected, especially by the employees of his firm, whose advancement, both educational and recreative, received his constant attention. Many institutions benefited by Mr. Walker's liberality, and he was greatly interested in astronomy and other sciences, having had an excellent observatory built at his residence. He contributed numerous articles to magazines and to learned societies, and was for many years a Justice of the Peace for the counties of Shropshire and Stafford, and was on one or two occasions selected as a candidate for Parliament. He was elected a member of the Iron and Steel Institute in 1886.

JOSEPH D. WEEKS died at Pittsburgh, Pennsylvania, on December 26, 1896, at the age of fifty-six. Born at Lowell, Massachusetts, he began his career in the ministry of the Methodist Episcopal Church. During the American Civil War he served on the Sanitary Commission, after which he became identified with the iron trade at Pittsburgh, and subsequently became editor of *The American Manufacturer*. On the amalgamation of the latter with *The Iron Age* he accepted the post of associate editor. In 1886, on securing the control of *The American Manufacturer and Iron World*, he relinquished his connection with *The Iron Age*. He was at the same time secretary of the Western Iron Association, and in 1878 visited Europe for the purpose of studying the labour question and the trades union movement, and of making a report to the Governor of Pennsylvania. He became a strong advocate of arbitration and conciliation, and was on one occasion selected by the coal-miners and operators as arbitrator in a great dispute. In 1880 he was appointed Government expert on the coke industry of the United States, and when the Geological Survey of the United States commenced the publication of mineral statistics, Mr. Weeks was appointed expert on coke, petroleum, manganese ore, and natural gas. He took a very active part in the introduction of European methods for the recovery of by-products in coking. He served on the Pennsylvania Tax Commission, and also held many other similar positions, both scientific, industrial, and social, and served as a judge in the Mines and Mining Department of the Columbian Exposition. He was an enthusiastic Freemason, and was prominent in temperance works. He was a valued and active member for many years of the American Institute of Mining Engineers, to which society he contributed a considerable number of papers. He had repeatedly held office on the Board of that Institute, and was in 1895 elected President. He was elected a member of the Iron and Steel Institute in 1878, and was an active member of the Reception Committee on the occasion of the visit of the Iron and Steel Institute to the United States in 1890.

# ADDITIONS TO THE LIBRARY

DURING THE FIRST HALF OF 1897.

Title.	By whom Presented.
“Bulletin of the Department of Labour.” Washington. 1896.	Mr. Carroll D. Wright.
“Spon’s Engineers’ and Contractors’ Diary and Yearbook.” London. 1897.	The Publishers.
“List of Quarries in the United Kingdom.” London. 1896.	Professor C. Le Neve Foster.
“Catalogue of Mathematical Instruments.” London. 1896.	Mr. W. F. Stanley.
“The Hardware Trade Diary.” 1897.	The Editor.
“The Presence and Influence of Oxides in Iron and Steel.” By W. Galbraith. (Pamphlet.)	The Author.
“ <i>Spirorbis</i> Limestone in the Permian Rocks of Wyre Forest.” By T. Crosbee Cantrill. (Pamphlet.)	The Author.
“Iron and Steel Industries at the Nichni Novgorod Exhibition.” By N. S. Verest- chaguin. (Pamphlet in Russian.)	The Author.
“Catalogue of the Michigan Mining School.” Houghton. 1896.	The Director.
“Shipping World Yearbook.” 1897.	The Editor.
“Report of the Department of Mines of Western Australia for 1895.”	The Department.
“Thirteenth Report of the State Mineralogist of California.”	Mr. J. J. Crawford.
“The Literary Yearbook.” London. 1897.	Purchased.
“Our Weights and Measures.” By H. J. Chaney. London. 1897.	Purchased.
“A Letter from the American Iron and Steel Association.” (Pamphlet.)	Mr. J. M. Swank.
“Lärobok i Mineralogien.” By A. Erdmann. Stockholm. 1860.	Mr. John Crum.

Title.	By whom Presented.
"Bidrag till Kändedomen om Sveriges Qvarterära Bildningar." By A. Erdmann. Stockholm. 1868.	Mr. John Crum.
"Lavra de Minas." Lisbon. 1872.	Mr. John Crum.
"The Bertrand - Thiel Process of Making Steel." By P. C. Gilchrist. London. 1897. (Pamphlet.)	The Author.
"Calendar of the Department of Science and Art."	Purchased.
Sell's "World's Press." London. 1897.	The Linotype Co.
"Papers Relating to the Boiler Inspection and Registration Bill." Manchester. 1897.	Mr. C. Longridge.
"Metallurgy of Cast Iron." By T. D. West. Cleveland. 1897.	The Author.
"Present Condition of the Iron and Steel Industries of the United States."	Mr. J. M. Swank.
Text - Books on "Heat," "Chemistry," "Mechanics," and "Sound."	Mr. W. B. Clive.
"Reminiscences of a Visit of the Iron and Steel Institute to Spain." By Henry Webb. Manchester. 1897. (Pamphlet.)	The Author.
"Stora Kopparbergs Grufna." By G. Andersson. Falun. 1897.	Mr. E. J. Ljungberg.
"The Works and Productions of Messrs. Head, Wrightson & Co." (Pamphlet.)	Mr. T. Wrightson.
"Capitolato per l'affitto delle regie miniere dell' isola d'Elba." Rome. 1897.	Mr. Bennett H. Brough.
"General Catalogue of Wire Ropes." Wakefield. 1897.	Messrs. George Cradock & Co.
"A Short Treatise on the Courts in Egypt from a Commercial Standpoint." By J. E. Marshall.	The Author.
"Digest of Physical Tests."	The Editor.
"El Arte Industrial en España." By Don Pablo de Alzola. Madrid. 1892.	The Author.
"Relaciones Comerciales entre la Península y las Antillas." By Don Pablo de Alzola.	The Author.
"The Handling of Material at the Blast-Furnace." By Axel Sahlin.	The Author.
"Summaries of Statistics Relating to the Mines and Quarries in the United Kingdom."	The Under Secretary of State.
"Memorandum on Maximum Railway Rates for Coal, with Notes and Appendix." By E. Dodshon. London. 1896.	The Author.
"The Determination of Carbon in Iron and Steel." By W. Galbraith. Glasgow. 1897. (Pamphlet.)	The Author.

Title.	By whom Presented.
“Notes on the Separation of Silicic and Tungstic Acids.” By J. S. de Benneville. Philadelphia. 1897. (Pamphlet.)	The Author.
“Die Bedeutung und neuere Entwicklung der Flusseisenerzengung.”	Mr. E. Schrödter.
“Crucible Making.” By J. A. Walker. New Jersey. 1897. (Pamphlet.)	The Author.
“Catalogue of the Library of the Horwich Technical School.”	The Secretary.
“List of the Plans of Abandoned Mines Deposited in the Home Office.” London. 1897.	Professor C. Le Neve Foster.

### INSTITUTIONS.

The Publications of the Institute are exchanged for those of the following Institutions :—

#### LONDON.

Board of Trade.  
 Chemical Society.  
 City and Guilds Institute.  
 Geological Society.  
 H.M. Patent Office.  
 Imperial Institute.  
 Institution of Civil Engineers.  
 Institution of Electrical Engineers.  
 Institution of Mechanical Engineers.  
 Institution of Mining and Metallurgy.  
 Institution of Naval Architects.  
 Royal Artillery Institution.  
 Royal Institute of British Architects.  
 Royal Institution.  
 Royal Society.  
 Royal Statistical Society.  
 Royal United Service Institution.  
 Society of Arts.  
 Society of Chemical Industry.  
 Society of Engineers.  
 University College.

#### PROVINCIAL.

Cleveland Institution of Engineers.  
 Hull and District Institution of Engineers.

Institution of Engineers and Shipbuilders in Scotland.  
 Liverpool Engineering Society.  
 Liverpool Polytechnic Society.  
 Manchester Association of Engineers.  
 Manchester Geological Society.  
 Mason College (Birmingham).  
 Merchant Venturer's School (Bristol).  
 Mining Institute of Scotland.  
 North-East Coast Institution of Engineers.  
 North of England Institute of Mining and Mechanical Engineers.  
 Sheffield Technical School.  
 South Staffordshire Institute of Iron and Steel Works Managers.  
 South Staffordshire Ironmasters' Association.  
 South Wales Institute of Engineers.  
 University College of South Wales.  
 West of Scotland Iron and Steel Institute.

#### **COLONIAL AND FOREIGN.**

##### **Colonial.**

Canadian Institute.  
 Canadian Society of Civil Engineers.  
 Department of Mines, Sydney.  
 Department of Mines, Melbourne.  
 Geological Survey of Canada.  
 Geological Survey of India.  
 Mining Society of Nova Scotia.  
 Royal Society of New South Wales.

##### **United States.**

American Association for the Advancement of Science.  
 American Institute of Mining Engineers.  
 American Iron and Steel Association.  
 American Society of Civil Engineers.  
 American Society of Mechanical Engineers.  
 Bureau of Statistics.  
 Engineers' Society of Western Pennsylvania.  
 Franklin Institute.  
 Ordnance Office, War Department.  
 School of Mines, Columbia College, New York.  
 Smithsonian Institute.  
 United States Geological Survey.

##### **Austria.**

K.k. geologisches Reichsanstalt.  
 Oesterr. Ingenieur und Architekten-Verein.

##### **Belgium.**

Ministère de l'Interieur.  
 1897.—i.

**France.**

- Comité des Forges.
- Le Ministère des Travaux Publics.
- “Revue Maritime.” Ministère de la Marine.
- Société d'Encouragement pour l'Industrie Nationale.
- Société de l'Industrie Minérale.
- Société des Anciens Élèves des Écoles Nationales d'Arts et Métiers.
- Société des Ingénieurs Civils.
- Société Scientifique Industrielle de Marseille.

**Denmark.**

- Tekniske Foreningen.

**Germany.**

- Königliche Bergakademie in Freiberg.
- Königliche Technische Versuchsanstalt.
- Verein Deutscher Eisenhüttenleute. (Journal “Stahl und Eisen.”)
- Verein Deutscher Ingenieure.

**Italy.**

- Reale Accademia dei Lincei.

**Japan.**

- Department of Mines.

**Sweden.**

- Jernkontoret.

**JOURNALS.**

The following periodicals have been presented by their respective Editors:—

**UNITED KINGDOM.**

- “Bimetalist.”
- “British Trade Journal.”
- “Coal and Iron.”
- “Commerce.”
- “Contract Journal.”
- “Colliery Guardian.”
- “Daily Tenders and Contracts.”
- “Electrician.”
- “Electrical Engineer.”
- “Engineer.”
- “Engineer and Iron Trades Advertiser.”
- “Engineering.”
- “Engineering Review.”

- “Engineers’ Gazette.”
- “Hardwareman.”
- “Hardware Trade Journal.”
- “Industries and Iron.”
- “Invention.”
- “Iron and Coal Trades Review.”
- “Iron and Steel Trades Journal.”
- “Ironmonger.”
- “Ironmongery.”
- “Iron Trade Circular.”
- “Marine Engineer.”
- “Machinery Market.”
- “Phillips’ Monthly Register.”
- “Plumber and Decorator.”
- “Practical Engineer.”
- “Railway Engineer.”
- “Railway World.”
- “Science and Art of Mining.”
- “Shipping World.”
- “Statist.”
- “Steamship.”
- “The London Technical Education Gazette.”
- “Tool and Machinery Register.”
- “Transport.”

#### **COLONIAL AND FOREIGN.**

##### **Colonial.**

- “Canadian Mining Review.”
- “Indian and Eastern Engineer.”
- “Indian Engineering.”

##### **United States.**

- “Age of Steel.”
- “American Journal of Science.”
- “American Manufacturer.”
- “Bradstreet’s.”
- “Cassier’s Magazine.”
- “Colliery Engineer.”
- “Digest of Physical Tests.”
- “Engineering and Mining Journal.”
- “Engineering Magazine.”
- “Engineering News.”
- “Iron Age.”
- “Iron Trade Review.”
- “Railroad Gazette.”
- “Report of Proceedings of the Master Car Builders’ Association.”
- “Stowell’s Petroleum Reporter.”

**Austria.**

“Oesterr. Zeitschrift für Berg- und Hüttenwesen.”

**Belgium.**

“Association des Ingénieurs de Liége.”

“Association des Maîtres des Forges de Charleroi.”

“Bulletin de l’Union des Charbonnages de Liége.”

“Moniteur des Intérêts Matériels.”

“Revue Universelle des Mines.”

**France.**

“Annales des Mines.”

“L’Echo des Mines.”

“Le Génie Civil.”

“Portefeuille Économique.”

**Germany.**

“Annalen für Gewerbe und Bauwesen.”

“Chemiker Zeitung.”

“Glückauf.”

“Verein Deutscher Eisen und Stahl Industrieller.”

“Zeitschrift für das Berg-, Hütten- und Salinenwesen, im preussischen Staate.”

“Zeitschrift für praktische Geologie.”

**Italy.**

“L’Industria.”

“Rassegna Mineraria.”

**Spain.**

“Revista Minera.”

**Sweden.**

“Teknisk Tidskrift.”

SECTION II.

*NOTES ON THE  
PROGRESS OF THE HOME AND FOREIGN  
IRON AND STEEL INDUSTRIES.*

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## IRON ORES.

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## I.—OCCURRENCE AND COMPOSITION.

**Iron Ore in Lanarkshire.**—In an account of the mineral seams of New Monkland, a parish of some 20,000 acres in the extreme north-eastern corner of Lanarkshire, J. Prentice\* gives some details of the various seams of iron ore which occur there. These are the Blackband seam, which attained its best development here, but is now worked out. Five feet below, the soft ironstone, an ore of poor quality, but worked to some extent, occurred over a narrow strip some 600 feet broad in the widest part. About 160 feet below, or 50 feet below the Ladygrange coal seam, is the Musselband ironstone and shale, but the ore is thin and of very inferior quality. Some 400 feet lower is the Slatyband ironstone, at the base of the Upper Coal measures. It varies often rapidly in thickness, but is of excellent quality. Workings have been carried on at four places, but now they are only working at Stanrigg. The Glenboig fire-clay seam is 720 feet lower, at the bottom of the Millstone Grit, and is six feet in thickness.

**Iron Ores of Hungary.**—A. Ritter von Kerpely † considers the present state of the iron industry of Hungary. The iron ore districts extend in the form of a semicircular belt from the west to the northwest, north, east, and south. In the west the ore deposits in the Zólyom, Gömör, Szepes, Abauj-Torna, and Borsod counties form a characteristic

\* *Transactions of the Federated Institution of Mining Engineers*, vol. xii. pp. 435-450.

† *Stahl und Eisen*, vol. xvi. pp. 932-933.

group. The ore found is mainly spathic carbonate, more or less converted from the outcrop to greater or lesser depths into brown haematite. In the Zólyom county, where the cradle of the Hungarian iron trade is probably to be sought, there now exists only one small furnace at work. The author deals in detail with a number of the different iron ore mines and ironworks in the various districts. Thus in the Vashegy ore field in 1895 four companies were at work, and they produced 184,757 tons of ore. Two ore deposits are mined in the Szepes county, and since 1890 these have yielded annually about 100,000 tons of ore. The ore is carbonate, and in 1895, 82,562 tons of this yielded on calcination 53,379 tons of calcined ore, which was exported in admixture with 13,574 tons of uncalcined small ore. Twenty-eight calciners were used, each treating 7 to 8 tons of ore in twenty-four hours, and requiring 4 tons of coke for every 100 tons of ore calcined.

M. Milosevics\* states that the Vashegy and Rákos iron ore deposits are the largest in the Gömör county, Hungary. They are known along their strike for a distance of 2·86 miles, and they have a thickness of from 13 to 121 feet. The ores are mostly spathic carbonate and brown haematite. As an interesting point, showing the improvements that have been made in mining during the last thirty years, the author mentions the fact that in 1867 in this county 1639 workpeople were required for the mining of 111,282 tons of iron ore, while in 1894 only 2145 were at work at the mines, yet the output reached 320,617 tons. That is to say, the output was nearly threefold, yet only some 30 per cent. more workpeople were employed. The following are analyses of iron ores from this county :—

	1	2	3	4	5	6	7	8	9	10	11
Fe <sub>2</sub> O <sub>3</sub>	54·5	46·86	60·60	72·72	59·63	71·52	77·31	39·88	72·78	45·89	78·21
MnO	2·5	2·53	...	1·72	1·05	...	0·82	7·00	8·15	2·45	2·84
SiO <sub>2</sub>	0·7	8·75	0·56	7·80	26·21	16·40	7·60	6·62	6·08	11·50	7·36
Al <sub>2</sub> O <sub>3</sub>	...	2·51	1·44	4·29	4·14	0·60	1·24	...	0·89	2·97	2·08
CaO	0·3	1·65	4·30	0·15	1·15	0·63	0·05	1·26	1·42	0·60	0·70
MgO	3·0	5·77	12·00	...	...	...	...	1·66	2·28	3·56	0·12
Cu	...	...	...	...	...	...	0·07	0·10	0·05	0·09	0·11
P <sub>2</sub> O <sub>5</sub>	...	0·04	...	...	0·39	0·16	0·92	0·29	0·36	0·08	0·16
S	trace	trace	...	...	0·23	0·07	0·11	0·42	0·35	0·41	0·40
CO <sub>2</sub>	38·6	31·39	...	...	...	...	23·40	...	31·80	...	

These ores were from :—(1) Nadabula ; (2) Dobsina ; (3) and (4) Vashegy ; (5) Rákos ; (6) Dernö ; (7) Vashegy, brown iron ore calcined ; (8) Vashegy, spathic carbonate ; (9) Vashegy, spathic carbonate calcined ; (10) Nadabula, spathic carbonate ; (11) Nadabula, spathic carbonate calcined.

\* *Stahl und Eisen*, vol. xvi. p. 886.

In the whole Hungarian monarchy the production of pig iron increased from 62,708 tons in 1855 to 319,400 in 1893. While, however, the production in this latter year only amounted to 0·018 ton per head of the population in the whole of Hungary, the production in the Gömör county was at the rate of 0·936 ton per head of the population. It is the difficulty of proper facilities for transport which has thus far stood in the way of the progress of the iron industry in Hungary.

The iron ore deposits of the Vashegy Mountains are enclosed in crystalline slates.\* Chloritic slates occur resting upon granite, and upon these again come the iron ore deposits, pockets and stockworks. The ores found are of very variable character, and are found also in masses of very variable size. The carbonate ores average about 38 per cent. of iron and 8 of manganese, only some 10 per cent. of the ore being insoluble in acids. This spathic ore passes by weathering into the so-called "black" ores. These average 46 per cent. of iron and 10 of manganese. The brown iron ores found on the hanging-wall side of the spathic carbonate deposits contain about 46 per cent. of iron and 4 per cent. of manganese. The spathic ores are calcined, and then in part conveyed to Likér by a wire ropeway. Another assay mentioned of the spathic ore shows 40 per cent. of iron and 10 of manganese. In 1895 the output of the Vashegy mines was 96,300 tons.

The ore deposit at Rakós is about 1·4 mile from the Vashegy deposit. The thickness of the ore varies from 10 to 45 yards. The ore so far mined here is limonite, with 38 per cent. of iron. Doubtless in the deep these will pass into spathic ores. These deposits yielded 35,000 tons of ore in 1895, and gave employment to 185 workpeople. Other ore deposits are also mentioned.

The alluvial deposit of iron ore at Tilfa Zappulni in Hungary is of very considerable extent, and is at no great distance from the well-known centre of Reschitza. The ore found consists mainly of rounded boulders, about 90 per cent. being magnetite, and the remainder red haematite. It resembles, therefore, the deposit of Pojana Wertop,† the other rocks occurring with the iron ore being also similar. The ore, however, occurs more frequently in smaller lumps, and three beds of it may be distinguished, of which the upper is only about a foot below the surface. The richest collections of ore and the largest ore pieces are found generally from 12 to 25 yards below the surface. The percentage of iron contained in the ores varies as a rule between 65 and 70, and the percentage

\* *Berg- und Hüttenmännische Zeitung*, vol. iv. pp. 314-316.

† *Ibid.*, p. 177.

of silica between 6 and 8. Undecomposed pyrites is occasionally found in the ore lumps, but, as a rule, the ore is very pure, and gives good results when treated in the blast-furnace.

In the South Hungarian mountains, not far from Bogschan,\* is a mass of gravelly deposit resting on crystalline limestone. It consists of portions of all the rocks of the district and of sand, and is over 50 yards thick in places, some of the blocks being from 2 to 3 cubic yards in size. It is probably a river deposit; the direction of the depositing current having apparently been such that the ore regions of the Dognatschka-Morawitza were probably passed through, the water carrying forward with it large masses of ore from this district, some of the ore blocks weighing 7 or 8 tons. Throughout its whole extent the deposit is mined by open workings. The largest quantities of iron ore are always found in the lower portions, and at those points where the limestone shows depressions. Magnetic iron ore and red haematite are present in almost equal quantities, but brown iron ore is entirely absent. Occasionally a little pyrites is found in the interiors of the ore pieces, but in general the ores are very pure. On an average, they contain about 65 per cent. of iron, and form a desirable ore source for the Reschitzia ironworks. The Wertop open work is in the form of an ellipse, the major axis of which is about 970 feet, and the minor 460 feet. There are four working faces, placed at heights of about 13, 26, 30, and 36 feet above each other. The method of mining is described, and with reference to the output it is stated that in 1894 about 1700 waggons of ore, each wagon containing one cubic yard, and 44,000 waggons of deads were hauled. The output of iron ore in 1894 was thus about 4100 tons. Sixty work-people are employed, working in twelve-hour shifts.

The Witkowitz Steelworks Company, and other companies named, possess in the Borsod district of Austria-Hungary brown haematite deposits which are mined.† Open working is employed, and two machine shovels are used. The ore is covered by sand, clay, &c., from 15 to 30 yards in thickness, and this is removed by the steam-shovels, which are worked by 10 horse-power engines. Each machine has a capacity of 80,000 or 90,000 cubic yards a year. A saving of about 22 per cent. is effected as compared with ordinary hand-labour. After removing the overburden, the ore is simply quarried. In 1895, 230,073 tons of it was mined, of which 15,000 tons went to Hungarian ironworks and the rest to the Witkowitz Steelworks.

\* *Berg- und Hüttenmännische Zeitung*, vol. lv. pp. 53-55.

† *Stahl und Eisen*, vol. xvi. pp. 975-977.

The most important iron ore deposits of Hungary are found in the Pojana-Ruszka range, which forms a part of the southern portion of the Királyhágó Mountains. The main portion of this mountain range consists of crystalline schist. Limestone also occurs in large quantity. Iron ore has been mined for centuries throughout the whole extent of these deposits, which appear rather to consist of a series of irregular lenticular masses. The largest has a thickness of 160 yards. This is at Gyalár, where the ore is brown haematite, though small pockets of red haematite and specular iron ore also occur. In 1895 the production of ironstone amounted to 138,000 tons, the method of mining adopted being open-work in six steps. The ore is conveyed by a narrow-gauge tramway to the small Gosvadia ironworks. Two wire ropeways, one of which is 18 miles in length, connect the Vajda-Hunyad blast-furnaces with the ore heaps of the Gyála mines. The longest of these also connects the furnaces with the Vadudibri Forest Charcoal Works. The second wire ropeway is 6 miles in length, and is used solely for the transport of ore to the furnaces.

**Iron Ore in the Hartz Mountains.**—In an exhaustive treatise on the minerals of the Hartz, O. Luedecke \* describes in detail all the minerals and rocks met with in that region. Red haematite and other iron ores are of frequent occurrence both in seams and in veins. Numerous analyses have been made of the red haematises of Elbingerode and Hüttenrode, but the ore is for the most part a mixture of various minerals. In the red haematite of the Thumkuhlenthal, Rammelsberg found 99·16 per cent. of ferric oxide and 0·84 per cent. of ferrous oxide. The specific gravity of the mineral was 5·627.

Titaniferous iron ore occurs in the Hartz granites, in the gabbro, and in other rocks. A specimen from the gabbro of the Bastei gave on analysis the following results :—

$TiO_2$ .	$Fe_2O_3$ .	$Cr_2O_3$ .	$Al_2O_3$ .	Gangue.
45·77	44·55	0·56	0·66	4·08

**The Oolitic Iron Ores of German Lorraine.**—L. Hoffmann † describes the minette iron ore deposits of this district,‡ which are found on an elevated tableland, termed the Plaine de Briey, from a place across the adjacent French frontier. This tableland falls steeply towards the

\* *Die Minerale des Harzes*, Berlin, 1896.

† *Stahl und Eisen*, vol. xvi. pp. 945-954, 988-998, with large map and two plates of sections.

‡ Compare *Journal of the Iron and Steel Institute*, 1895, No. I. p. 276

Moselle, but slopes gently towards the west. It is traversed by deep valleys. The average elevation of the tableland is about 980 feet. The highest point is near Oettengen, close to the Luxemburg frontier, the altitude of which is 1475 feet. The edge of the tableland where it falls off steeply towards the Moselle is, on the average, about 650 feet above the bed of that river, into which waterway all the streams from the German portion of this territory fall. Of these, the Feutsch and Orne are the most important. The beds forming this plateau belong mainly to the Dogger beds of the Jurassic formation, surrounding the Cretaceous beds of Northern France. The lower beds of the Dogger belong to the *Astarti Voltzi* clays, and above these come the *Trigonia navis* and *Ammonites Murchisonæ* beds with seams of iron ores. The Dogger is faulted in a number of places, some of the faults being considerable. The *Trigonia navis* and *Ammonites Murchisonæ* beds are in their lower measures clay, marls, and sandstone. Above these come the iron ore seams, with partings of sandstone, marl, and oolitic limestone. There are five chief seams of ore, termed from top to bottom "Red sandy," "Red calciferous," "Yellow," "Grey," and "Black." There are also some minor seams. The author gives a list of the various papers, maps, &c., which have been published in connection with this district since 1861.

The thickness of the ore seams diminishes from north to south. Thus, while in Luxemburg they have a total thickness of 75 feet, at Ars only the "Black" seam is left, its thickness there being 5 feet. The percentage of iron in the ores raised may be considered to amount on the average to 36. A seam ceases to be capable of being mined to commercial advantage when its thickness is less than a yard, or its iron contents fall below 30 per cent.

The author first discusses the iron ore district between the Fentsch and St. Privat-la-Montagne, an area of about 60 square miles. The active mines in this district raised, in 1895, 2,656,767 tons of ore, and gave employment to 2242 workpeople. The following are analyses of the ores found in the different seams:—

	Red Sandy.	Red Cal- careous.	Yellow.		Grey.		Lower Brown.	Black.	
	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.
Ferric oxide .	44·5	57·14	51·73	34·06	57·14	53·44	49·04	42·85	47·28
Lime . .	5·3	9·50	12·30	22·45	7·00	9·20	8·63	6·00	10·16
Silica . .	33·6	7·50	8·46	15·00	9·00	6·80	16·59	24·50	15·82
Alumina . .	4·2	5·00	{ } 4·17	9·45	{ } 6·00	{ } 9·96	6·44	{ } 10·00	6·37
Phosphorus pentoxide .	{ } 1·6	1·80							
Magnesia . .	9·5	1·20	1·37	{ } n. d.	{ } 1·60	{ } 0·25	2·00	1·50	2·76
Manganese sesquioxide .	{ } n. d.	0·25	{ } n. d.						
Sulphur . .	trace	trace	{ } n. d.	{ } n. d.	trace	{ } 17·00	19·60	15·02	13·00
Loss on ignition . .	{ } 10·7	17·50	20·98						
Totals . .	109·4 *	99·89	99·01	...	99·69	99·00	97·72	99·75	99·66 †
Percentage of iron . .	{ } 31·15	40·00	36·21	23·84	40·00	37·41	34·33	30·00	33·10

In the above table, n. d. represents in each case "not determined." Another sample from the "black" bed shows 40·80 per cent. of silica, the percentage of iron amounting to 18·30.

The author devotes considerable attention to the faulting observed in this district, and next discusses seriatim the different mines and boreholes with reference to the ore seams, their thickness, analysis, and absence of one or other of the seams, &c. Thus at the Hayingen mine he shows that only the "grey" seam of ore is worth mining, while the "red sandy" bed is replaced by ferruginous limestone, and the "red calciferous" is entirely absent. The ore in the "grey" bed as mined averages here 34 per cent. of iron, 9 of lime, and 7 of silica. At the Neufchef mine, on the other hand, all five seams are mined, and analysis shows the ore of the "yellow" bed to have approximately the same composition as that from the "grey" seam. The others are similarly treated, full details being given in each case.

Other boreholes which the author mentions include the Prince August, III and II, and Neunkirchen, III. and IV., Nos. 32 and 33, and 34 and 35 respectively. The boreholes Ida I. (No. 37), and II. (No. 36), and St. Marie-aux-Chênes (No. 38), are also described. Boreholes 32 and 33 both showed that the grey bed of ore was of adequate size for mining purposes. It is over 8 feet in thickness, and after separating from it about 25 per cent. of the calcareous ore, analysis showed the remainder to contain :—

\* 100·4 in original.

† 99·72 in original.

	Borehole 33.	Borehole 32.
	Per Cent.	Per Cent.
Iron . . . . .	39·05	36·74
Lime . . . . .	7·68	9·28
Silica . . . . .	7·41	7·97
Alumina . . . . .	6·98	6·76

The yellow bed of ore is at this spot not of sufficient size to admit of its being mined, but the red calcareous ore beds seemed likely, in part, to yield a satisfactory result. The upper "brown bed" was found in these boreholes to be over 10 feet in thickness. From borehole 32, after separating 14 per cent. of calcareous ore, the average analyses showed the bed of ore to contain :—

Iron.	Lime.	Silica.	Alumina.
40·25	9·32	6·24	6·94

Analysis of samples from the hanging and foot wall portions of the bed averaged, without any previous separation of the ore, 30 per cent. of iron. Analyses of the bed as found by borehole 33 showed the following results :—

	I.	II.
	Per Cent.	Per Cent.
Iron . . . . .	39·35	36·78
Lime . . . . .	10·01	11·25
Silica . . . . .	7·00	7·28
Alumina . . . . .	7·10	6·96

Analysis I. represents the first  $8\frac{1}{2}$  feet of ore from the hanging-wall, analysis II. the remaining  $5\frac{1}{2}$  feet. Before making these analyses, however, 25 per cent. of calcareous ore was first separated from the samples. The "black" bed did not prove of value. Below this again a "green" bed was met with. This bed has been found in several different boreholes. In one case it had a thickness of 12 feet, and contained :—

Iron.	Lime.	Silica.
22·81	14·56	26·81

Full details are given explanatory of a number of sectional elevations of the field, and then considering the district as a whole, the author observes, that the five main beds of ore are mostly all present in the northern portion of the field. They thin out gradually towards the

south, the "red-sandy" bed reaching only to the Orne. The next to disappear is the "red calcareous" bed, and then the "grey."

In the south of German Lorraine, near Ars, only the "black" bed is found. The "yellow" bed also thins out and disappears therefore towards the south. Of secondary beds, the upper and lower "brown" ones, between the "grey" and the "black," are to be noted. The first lies about in the middle of the marl which separates the two main beds, and it occurs only south of the Orne, and towards the frontier line. The lower "brown" bed is found on both sides of the river close to the "black" bed. In addition, there is also the "green" seam, previously referred to. The average thickness of the ore beds may be taken at about 10 yards, increasing to 17 yards as the French frontier is approached. This increase in thickness is due far more to an increase in the thickness of the seams of ore than to an increase in that of the partings. The yellow and the black seams show the smallest changes. The marl parting between the black and grey seams, apart from the most southern portion of the district, is nearly everywhere about 6 yards, while the parting of ferruginous oolitic limestone between the grey and the yellow beds is usually about  $4\frac{1}{2}$  feet in thickness. In addition to this regular variation in the thicknesses of the seams, local variations also occur. As is usual in all sedimentary deposits, both the regular diminution in thickness of the seams and diminution in the percentage of iron contained in the ore is also observed.

The author points out the areas over which the various seams of ore are thick enough and rich enough to be worth mining, and observes that the percentage of silica contained in the minette is greatest in the top and the bottom seams, and is less in the middle beds of ore. In the northern portion of the district, the strike of the beds is about N.  $10^{\circ}$  E., in the south it is N.  $25^{\circ}$  E. The greatest dip is 6·5 per cent., but on the average it may be taken at 1·5 per cent. Taking all the district into consideration, the reserve of ore appears to be about 605,895,000 tons, or enough for another 224 years' output, when that of 1895 is taken as a basis. In exact figures this amounted to 2,656,767 tons, but for the purpose of his calculation the author takes it at 2,700,000 tons. The author compares this with other calculations as to this reserve of ore. He next considers in general the mineralogical and petrographical nature of the deposit. As regards the structure of the minette, this consists of round, ellipsoidal or irregularly-shaped grains, on the average 0·25 millimetre in diameter, and built up of concentric layers. They consist of ferric hydrate and amorphous silica, which remains as a skeleton

when the grain of ore is treated with hydrochloric acid. A quartz granule probably forms the core of the ore particle. A bedding or parallel structure is not observable in the ore particles and a line of least cohesion cannot be detected. The hardness is far below 3, and if a pointed tool is passed over a seam of ore, the ore proper is very readily distinguished from the harder calcareous portions mixed with it. The colour of the ore frequently does not agree with the name of the seam. Thus while the two "red" and the two "brown" beds do fairly well accord in colour with their names, brown is the chief colour noticed in the "yellow" and in the "grey" beds, reddish and grey colorations being also frequently noticeable. The minette of the "black" bed is mostly grey-green in colour. Accessory minerals are calc spar, pyrites, magnetite, zinc blonde, galena, and heavy spar, the three last being very rare. Marl patches are found in all the seams of ore. The author gives analyses of the harder calcareous portions of the different seams, showing how closely they approach in general composition to the ore itself. With regard to the mode of origin of the iron ore seams, the author observes that they must either have had their origin in the replacement of constituents of other rocks by the action of iron solutions or by direct deposition. He shows that the origin by replacement is impossible for various reasons, and he attributes the seams to direct deposition *in situ*, and not to such secondary action. The oolitic structure is due to the ore particles having formed around sand grains and to the subsequent movement caused by water currents.

The following are analyses of the calcareous portions of the ore already referred to :—

	Red Sandy Seam.	Red Calcareous Seam.	Grey Seam.	Black Seam.
	Per Cent.	Per Cent.	Per Cent.	Per Cent.
Ferric oxide . . . . .	10·0	35·7	30·0	17·4
Lime . . . . .	46·0	26·0	29·0	33·0
Silica . . . . .	4·0	5·0	4·0	11·0
Alumina . . . . .	1·0	4·2	4·5	4·0
Phosphorus pentoxide . . . . .	0·5	1·4	1·1	0·7
Magnesia . . . . .	0·5	0·7	1·1	1·0
Manganese sesquioxide . . . . .	0·4	0·3	0·3	0·6
Sulphur . . . . .	trace	trace	trace	trace
Loss on ignition . . . . .	37·5	26·5	30·0	32·0
Totals . . . . .	99·9	99·8	100·0	99·7

These agree respectively with the following percentages of iron :— 7·0; 25·0; 2·10; and 12·0.

**Russian Iron Ore Deposits.**—Up to now the manufacture of pig iron in Southern Russia has been mainly dependent on the iron ore deposit of Krivoirog.\* Now, however, discoveries have been made in the Kertsh peninsula, and on that of Taman, which show the presence of very large bodies of iron ore. The brown iron ore of this district is not very rich in iron. On the average the unwashed ore contains 38 per cent. of iron and 1·5 of phosphorus. Blast-furnace runs with this ore have been made at the Alexandroff works, and have given complete satisfaction. The ore is suitable for the basic process, a very good quality of metal resulting, especially well suited for the manufacture of the thin roof-sheeting of which large quantities are now imported into Russia from Germany. On the Kertsh peninsula the ore is found in beds of from 14 to 42 feet in thickness, and outcrops frequently, or is only covered by a thin layer of soil. So far the ore has been found for about 33 to 40 miles along the coast, and in very large quantities near Jenikale, Jansch, and elsewhere. This discovery is of the greatest importance for the ironworks of the Sea of Azov district, as it ensures them a supply of ore for many decades to come.

J. Kowarsky † observes that in the eight governments which comprise the Moscow ore field only 200,000 tons of ore are mined in the year. Transport difficulties are considerable. The ore contains from 35 to 60 per cent. of iron, and usually averages about 50 per cent. in the uncalcined, and 59 in the calcined ore. An average analysis of the ore smelted at the Kulebaki works is as follows:—

	Per Cent.
Ferrio oxide . . . . .	70·0
Manganous oxide . . . . .	2·0
Alumina . . . . .	2·0
Lime . . . . .	1·0
Magnesia . . . . .	0·6
Silica . . . . .	10·0
Phosphoric anhydride . . . . .	0·5
Loss on ignition . . . . .	12·0
Total . . . . .	98·1

The cost of the ore at the mines is from 8 to 12 kopecks per pood, as compared with 2 to 3 kopecks in the Ural, and about 5 in South Russia and in Poland.

A deposit of iron ore of considerable size is stated to have been discovered in the neighbourhood of Yeniseisk in Eastern Siberia. The ore is stated to be of excellent quality.‡

\* *Stahl und Eisen*, vol. xvii. p. 229.

† *Ibid.*, vol. xvi. p. 860.

‡ *Western Daily Press*, November 28, 1896.

**Iron Ore in Servia.**—R. Helmhacker\* observes that iron ores are of frequent occurrence in Servia, but means of communication are so poor that but very little mining is done. The Rudnik Mountains are rich in iron ore, which consists of carbonates changed into brown iron ores at the outcrops. Small quantities of manganese ore are always contained in admixture with them. The Veucuca ores contain from 49 to 38 per cent. of iron, 0 to 3·25 per cent. of manganese, and 13 to 18·25 per cent. of silica. Rich ores contain up to 56 per cent. of iron, and 5·4 of manganese.

Manganese ores are found at Rudnik and Samokov in the Leskovac district. Manganiferous iron ores containing some 37·3 per cent. of manganese and 16 per cent. of iron are of frequent occurrence, but ores with 56 per cent. of manganese are less frequent.

Chrome iron ore is mined in small quantities, and exported to London. Fireclays occur in many places.

**Indian Iron Ores.**—Some time ago the Scientific and Technical Research Department of the Imperial Institute received from the Revenue and Agriculture Department of the Government of India specimens representing the iron ores yielded by mines in the Madras Presidency, and chiefly from the mountain ranges in the vicinity of Salem. The metal in these ores is in all cases in the form of oxides; the samples include varieties of magnetite, quartz magnetite schist, and magnetic sand. They vary very considerably in richness; thus No. 793, from the northern flank of the Kollimalais, contains 70 per cent. of available iron, whilst a quartz magnetite schist from the same locality contains only 30 per cent. of iron, and more than 50 per cent. of silica and gangue, insoluble in acids. The whole of the samples contain magnetic oxide in various proportions, and in no case was any titanium found. Phosphoric acid and sulphur are not present in any one instance in considerable proportions, and generally they are present as traces only. Manganese is not present in more than minute quantities in any of the samples. The method of examination pursued was as follows:—A representative sample of the ore, reduced to very fine powder, was digested with *aqua regia*, and the insoluble residue, after ignition, weighed as silica and gangue. In the filtrate were determined the remaining constituents. The total iron was estimated by reduction and titration against standard bichromate in the usual manner, and, by means of a separate estimation of the ferrous oxide in a fresh sample of the ore, digested with hydro-

\* *Berg- und Hüttenmännische Zeitung*, vol. lv. p. 138.

chloric acid in a neutral atmosphere, the amount of iron in the ferric state was arrived at. The phosphoric acid and sulphur were determined in the ordinary way by precipitation with ammonium molybdate and "magnesia mixture," and with barium chloride respectively. The proportions of alumina present were arrived at by difference, the combined weights of ferric oxide and phosphoric acid being subtracted from the total precipitate obtained with ammonia. The following is a description of some of the samples of ore examined, with the analytical results furnished by each :—

*Magnetite* (from Kanjamalai, Salem District). — A blackish-grey, lustrous, strongly magnetic mineral, containing small patches of a white substance, which consisted of aluminium and calcium phosphate.

	Per Cent.
Total moisture . . . . .	0·59
Ignited insoluble residue . . . . .	1·04
Ferrous oxide . . . . .	20·97
Ferric oxide . . . . .	75·20
Alumina . . . . .	2·45
Phosphoric acid . . . . .	0·30
Sulphur . . . . .	0·16
Manganese and lime . . . . .	traces

*Quartz Magnetite Schist* (from the Salem District; mined by the native iron-smelters on the northern flanks of the Kollimalais).—This was a dark-grey, friable, and magnetic ore, with red-brown veins interspersed, and a large amount of siliceous matter.

	Per Cent.
Total moisture . . . . .	1·35
Silica and gangue . . . . .	53·22
Ferrous oxide . . . . .	4·14
Ferric oxide . . . . .	41·00
Phosphoric acid . . . . .	0·30
Sulphur . . . . .	0·30
Alumina . . . . .	0·12
Lime . . . . .	0·30

The following statement shows the total percentage of iron in each sample, of which complete analyses are given :\*—

\* *Journal of the Imperial Institute*, vol. ii. pp. 223-224.

Serial No.	Locality.	Available Iron.
<i>Magnetite—</i>		
799	Kanjamalai, Salem district . . . . .	68·95
812	Do. do. . . . .	36·44
813	Do. do. . . . .	35·73
815	Do. do. . . . .	70·06
873	Do. do. . . . .	68·57
874	Do. do. . . . .	66·96
793	Northern flanks of Kollimalais, three miles south of Namagiri-pett, Salem . . . . .	69·75
802		37·38
848	Northern flanks of Kollimalais, Salem district . . . . .	37·63
<i>Magnetite " sifted "</i> —		
800	Namagiripett, Salem district . . . . .	68·40
808	Mathurulii, Attur Taluq, Salem . . . . .	60·21
810	Kollimalais, Salem district . . . . .	68·06
<i>Quartz Magnetite Schist—</i>		
795	Northern flanks of Kollimalais, Salem district . . . . .	31·92
796	Northern flanks of Kollimalais, three miles south of Namagiri-pett, Salem district . . . . .	32·17
821		42·93
860	Murugathii Malai, W.S.W. of Attur, Salem district . . . . .	43·30
861	Wandur, Ernad Taluq, Malabar district . . . . .	45·10
<i>Magnetic Sand—</i>		
852	Wandur, Ernad Taluq, Malabar district . . . . .	60·33
801	Mathurulii, Attur Taluq, Salem district . . . . .	63·43
809	Mathurulii, four miles west of Mallikari, Attur Taluq, Salem district . . . . .	65·22

J. P. Goodridge \* directs attention to the accumulation of iron ore in the metamorphic rocks of Chanda, in the Central Provinces of India. The most noted and accessible localities (distant only a few miles from the G. I. P. Railway at Warrora) are (1) Lohara (or the iron mountain), where compact crystalline haematite of extreme purity, containing 70 per cent. of metallic iron, forms an entire hill three-eighths of a mile long, 200 yards broad, and 120 feet high; (2) Dewalgaon, where there is also a hill of haematite 250 feet high; (3) Pipalgaon, where there is an enormous amount of similar ore with magnetic oxide; and (4) Ratanpur, where there is a very rich lode of brown iron 40 feet and 50 feet thick in places. There are numerous other places in the Chanda district where immense deposits of haematite and magnetite are found. Their great value lies in the almost total freedom of the ores from phosphorus.

**Iron Ore in Newfoundland.**—J. P. Howley, of the Geological Survey of Newfoundland, states in a recent report † that the Colony pos-

\* *The Times*, April 27, 1897, p. 12.

† *Colliery Guardian*, vol. lxxii. p. 1063.

seses magnetite, chromite, and haematite deposits. A bed of magnetite at Tilt Cove is 4 to 30 feet in thickness. The most extensive deposits of this mineral occur, however, near St. George's Bay, where one mass is over 50 feet in thickness, and contains 65·05 per cent. of iron.

**Iron Ore in Alabama.** — The iron ores of Alabama are discussed by W. B. Phillips at some length in a monograph on iron-making in Alabama.\* Practically all the iron in this State is made from limonite and haematite, and these generally occur with 0·10 to 0·40 per cent. of phosphorus and 50 per cent. of iron. The ore is not sold by analysis, as it should be. The haematites are the soft-red and the hard-red or calcareous ores, of which the latter carry 12 to 20 per cent. of lime, and are often self-fluxing. Some encouraging results have been attained in the endeavour to magnetically concentrate the soft ores, and some advantage is gained by using the calcined hard ores direct. The brown ores occur extensively as pebbles or boulders mixed with clay, and are concentrated by washing, and sometimes are calcined. The fluxes, limestone, and dolomite are also dealt with, and a number of analyses of ores and fluxes are given.

H. M'Calley † describes the geological occurrence of limonite in Alabama. These mostly occur in irregular pockets of boulders, nodules, and pebbles, but many are in regular stratified seams, from which the former are derived. The pocket deposits are most common along lines of major faults and badly broken-up strata, and hence are most numerous along the south-east edge of the Palæozoic region. The matrix, loam, &c., is often so deep as to completely hide the strata underneath. Many of the deposits are much younger than the underlying rocks, and are doubtless derived from them. The author gives a table of the subdivisions below the Coal measures, to show the position of the largest and most workable deposits. These lie at and near the top of the Weisner quartzite (Chilhowee), at the base of the Cambrian; at and near the bottom of the Siliceous (Knox) Dolomite and Chert group, at the base of the Lower Silurian; and third, at and near the bottom of the Lauderdale (Keokuk) Chert group, at the base of the Lower Sub-Carboniferous formation. The first of these deposits are numerous and extensive, and forms the outcrop of one or two strata which alter into quartzite and quartzitic conglomerate. Sometimes they are several hundred yards long and 40 to 50 feet in thickness. The pocket ore occurs as boulders in deep red loam, and is extensively worked. The

\* *Iron-making in Alabama*, Alabama Geological Survey, 1896, pp. 13-63.

† *Engineering and Mining Journal*, vol. lxii. pp. 583-585, with two illustrations.

ore is a black waxy ore, high in iron, silica, and phosphorus, and is best in the pockets. In the second group are the best and most widely worked limonite deposits in the State, some having been worked to a depth of nearly a hundred feet without reaching the floor. Here again the pocket ore is the better. The third series are of similar character, but are the least important of the three. The largest manganese deposit is at the bottom of this group. Limonite is also found on two horizons in the Upper Sub-Carboniferous age ; also smaller deposits are found in more recent formations.

According to H. M'Calley,\* haematites occur in Alabama in regular stratified seams, somewhat local in occurrence and importance, in Upper Silurian, Lower Silurian, and Cambrian formations. Only those in the Upper Silurian are of commercial value, and they are the most important iron ores in the country. As these deposits are close to coal and fluxes, they are most extensively mined, although the iron contents are not very high. The rocks of the Upper Silurian age range in thickness up to 700 feet, and in their central part contain the most ore, forming the Red Mountain strata. Ores are found outcropping over some 500 miles, but are workable only in parts where they occur in one to five seams ranging from a few inches up to 30 feet in thickness. The workable Clinton ores are confined to the anticlinals and synclinals north-west of the greatly-faulted strata of the Appalachian region. The Big or Red Mountain seam, which has supplied most of the ore for the twenty-five furnaces of the Birmingham district, splits up into two layers towards the south-west, and near Bessemer they are five feet apart. Over nearly the whole of the eleven miles between these places the upper layer has been worked on the outcrop. The seam dips 25° to 35° for 500 to 600 feet, and then becomes flatter. Besides the open workings, there are five-and-twenty underground mines, one yielding a thousand tons daily. The lower part of the seam will be worked later, as it is said to give magnetic concentrates containing 56 to 58 per cent. of iron without roasting. The outcrop ore contains in the upper layer 45 to 50 per cent. of iron, but deeper in the ore contains more lime, and only 35 to 40 per cent. of iron.

According to W. M. Brewer,† the output of iron ore, of fluxes, and of iron in Alabama during 1896 was somewhat less than in 1895.

**Iron Ore in California.**—Some valuable deposits of iron ore occur in California, but at present are not worked, according to the State

\* *Engineering and Mining Journal*, vol. lxiii. pp. 43-44.  
1897.—i.

† *Ibid.*, pp. 16-17.

report,\* which mentions this material as occurring in four counties. Manganese ore also occurs in six counties, but is practically undeveloped or the workings are idle.

**Iron Ore in New Jersey.**—J. E. Wolff and A. H. Brooks † have carefully studied the age of the white limestone of Sussex County, New Jersey, which is of interest in connection with the iron and zinc ores associated with it. Reasons are given for referring this rock to the Pre-Cambrian period instead of considering, as has been done recently, that it is a metamorphosed blue limestone of Cambrian age.

The extended litigation with regard to the rights in the zinc and franklinite ores of Mine Hill, New Jersey, has now come to an end after lasting some forty years.‡ When the property was first transferred in 1848, the rights to zinc ore and to franklinite were conveyed to different people, whilst the willemite or anhydrous silicate of zinc was not at the time utilised. When the zinc value of the franklinite was discovered shortly before 1857, the litigation began, and continued under various forms, with the view of showing that the franklinite ought to be considered zinc ore, as that metal was the most valuable constituent; but this view has now been definitely upset. The deposit is believed to be without parallel in the United States. It has been very fully explored both by workings and by borings; and while its limits are well defined, it still contains a vast amount of valuable ore, exceeding the quantity removed in the last fifty years. The chief constituents are zinc, iron, and manganese.

**The New York Magnetites.**—A monograph covering fifty-eight pages, and including numerous maps and sections, by J. F. Kemp, § deals with the geology of the magnetites near Port Henry, New York, and especially those of Mineville, where, with two exceptions, they form the largest single group yet developed east of Lake Superior. The conclusions arrived at confirm those of previous observers. The ores here occur on the contact of the gabbro and the gneiss. The general topography, distribution of the mines, and general geology are first sketched,

\* Thirteenth Annual Report of the Californian State Mining Bureau, 1896, pp. 504, 506-507.

† Paper read before the Geological Society of America, through the *Engineering and Mining Journal*, vol. lxiii. p. 40.

‡ *Engineering and Mining Journal*, vol. lxii. pp. 530-531.

§ *Transactions of the American Institute of Mining Engineers*, 1897, Chicago meeting (advance proof).

and then the various non-titaniferous ore bodies are dealt with at some length, after which the enclosing rocks are described in detail, being illustrated with microscopic sections. The geological relations of these gabbros and gneisses are then considered, and the various views as to the origin of the ore are discussed. The author advances the conception of an origin by contact metamorphism as one of strong probability. The various minerals found in the district are described, and a bibliography is appended.

**Classification of Mineral Deposits.** — H. Höfer \* publishes in tabular form a classification of the different kinds of mineral deposits. This he discusses, dealing separately with the different kinds of deposits.

**Thallium and Molybdenum in Iron Ore.** — L. J. Igelström † has carefully analysed the specular iron ore occurring in association with numerous rare minerals at the Sjö mine, Örebro, Sweden, and finds that in some cases it contains thallium, molybdenum, and calcium, and in others only molybdenum.

**Burnt Pyrites.** — An analysis of a sample of burnt pyrites from the works at Rannersdorf, according to E. Priwoznik,‡ shows :—

	Per Cent.
Ferric oxide . . . . .	85·48
Ferrous oxide . . . . .	4·37
Copper oxide . . . . .	0·52
Lead oxide . . . . .	0·054
Bismuth oxide . . . . .	trace
Silver . . . . .	0·007
Gold . . . . .	0·00002
Antimony sesquioxide . . . . .	0·023
Arsenic sesquioxide . . . . .	0·021
Nickel oxide . . . . .	0·040
Cobalt oxide . . . . .	trace
Zinc oxide . . . . .	trace
Silica . . . . .	5·65
Sulphuric anhydride . . . . .	2·82
Phosphoric anhydride . . . . .	0·037
Lime . . . . .	0·40
Magnesia . . . . .	0·70
Total . . . . .	100·07202

\* *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xlv. pp. 153-156.

† *Zeitschrift für Krystallographie*, 1896, p. 94.

‡ *Berg- und Hüttenmännische Zeitung*, vol. Iv. p. 402.

The analysis is interesting from its very complicated character. The burnt pyrites contains 63·2 per cent. of iron.

**Recent Researches on Meteorites.**—W. Ramsay\* and M. N. Travers have investigated the gaseous constituents of certain specimens of meteoric iron, with the following results:—

*Greenbrier County Meteorite*.—Ten grammes of metal gave a fairly large quantity of gas on heating, which consisted wholly of hydrogen.

*Toluca Meteorite*.—One gramme gave 2·8 cubic centimetres of pure hydrogen.

*Charca Meteorite*.—One gramme gave 0·28 cubic centimetre of hydrogen.

*Rancho de la Pila Meteorite*.—One gramme gave 0·57 cubic centimetre of gas. It consisted of hydrogen.

*Obernkirchen Meteorite, from Schaumburg-Lippe, Germany*.—One gramme gave 2·6 cubic centimetres of gas.

The gases from these meteorites were exploded with oxygen, and were found to contain no trace either of argon or helium or of nitrogen. The carbon compounds present were possibly produced by the decomposition of the oil, &c., with which the shavings of meteoric iron had become contaminated.

It will be remembered that a previously examined specimen of meteorite was found to contain both argon and helium.

A most interesting account of the worship of meteorites, delivered as a lecture by the late Professor H. A. Newton in 1889, but only just recently published,† contains references to this practice collected from different ages all over the world. In the Ohio mounds a mass of meteoric iron was found on a brick altar. North of Zanzibar a meteorite that fell in 1853 was worshipped by a tribe for many years, until they were decimated by the Massai. India furnishes examples of meteorites worshipped as deities, and also of others treated in a reverse fashion. In Japan some of these stones have been cherished as heirlooms, and in China during certain dynasties careful records were kept of falls. The Emperor Maximilian, in 1492, held a council of state to determine what message from Heaven was brought by a 300 lb. meteorite that fell in Alsace, and other European falls were treated with much consideration. In the Kaaba, at Mecca, the Moslems reverence a stone which is believed to be a meteorite which was worshipped long before the time

\* *Proceedings of the Royal Society*, vol. ix. p. 445.

† *American Journal of Science*, vol. iii. pp. 1-14.

of Mohammed, and many Greek and Latin writers mention the reverence paid by Arabians, and by many other nations, to meteorites, or to portents heralded by their fall. All these nations, in fact, worshipped or held in high regard these Heaven-sent messengers, and the early writers are fertile in references to such matters.

W. M. Foote \* gives an account of a meteorite from the Sacramento Mountains, Eddy County, New Mexico, which probably was seen to fall in 1876. It belongs to the class of siderites, and is quite soft and homogeneous. It measures 31·5 by 23·6 by 0·79 inches, and weighs 52½ lbs. Widmannstätten figures are well developed. On analysis it shows :—

Iron.	Nickel.	Cobalt.	Total.
91·39	7·86	0·52	99·77

A catalogue of the collection of meteorites in the Peabody Museum of the Yale University has been published,† giving the date and place of fall as far as known, and the weight. It includes ninety-nine meteoric stones and 102 meteoric irons.

In No. III. of his "Meteoritic Iron Studies," E. W. Cohen ‡ gives analyses of several irons, and of the isolated rhabdite needles. It is shown that the acicular rhabdite and the platy schreibersite have the same chemical composition, namely,  $(\text{Fe}, \text{Ni}, \text{Co})_3\text{P}$ ; the two occur together, and only differ in habit. Goniometric measurements of rhabdite needles showed the existence of a tetragonal prism zone. The irons examined were :—I. See-Läsgen, Prussia; II. Bolson de Mapimi [= Coahuila], Mexico; III. Sanchez Estate, Mexico; IV. Hex River Mountains, South Africa; V. Schwetz, Prussia; VI. Rasgata, New Granada; VII. Lime Creek [= Claiborne], Alabama. The mineralogical composition of these is as follows :—

	I.	II.	III..	IV.	V.	VI.	VII.
	Per Cent.						
Nickel iron . . .	98·76	98·344	98·49	97·99	98·55	97·10	96·96
Ni-Fe phosphides . .	1·21	1·615	1·49	1·97	0·17	1·73	2·91
Carbon . . .	0·01	0·011	} 0·02	0·02	0·01	0·07	0·01
Chromite and silicates . .	0·01	0·003		} 0·02	0·02	0·03	0·09
Daubréelite . . .	0·01	0·027	...		...	...	0·03
Ténite . . .	...	...	...	...	0·89	0·15	...
Angular fragments . .	...	...	...	...	0·36	0·56	...
Insoluble . . .	...	...	...	...	...	0·36	...

\* *American Journal of Science*, vol. iii. pp. 65-66.

† *Ibid.*, pp. 83-86.

‡ *Journal of the Chemical Society*, vol. lxxii. pp. 56-57.

The action of acid on the different irons of similar chemical composition is very variable, solution taking place in a few days, or only after an interval of months. Analysis of the portions soluble in dilute hydrochloric acid gave :—

	Fe.	Ni.	Co.	P.	Cu.
	Per Cent.				
I.	92·23	7·24	0·47	0·04	0·02
II.	94·22	5·17	0·54	0·06	0·01
III.	92·47	6·68	0·63	0·0469	0·0148
VI.	92·29	5·50	0·84	0·15	0·02
VII.	93·86	4·97	0·76	0·16	0·01

Analysis of the isolated rhabdite needles gave :—

	Fe.	Ni.	Co.	P.	Cr.	S.	Residue.	Total.
	Per Cent.							
I.	49·06	35·48	0·46	13·36	0·48	0·68	0·63	100·03
II.	51·60	30·89	0·70	14·63	0·78	...	0·96	99·56
III.	55·01	28·63	0·60	15·24	0·43	...	...	100·19
IV.	55·54	26·73	0·46	15·10	0·26	0·30	...	98·91
VII.	47·22	30·16	0·38	14·16	0·95	1·16	...	96·57

With III. there is 0·28 per cent. of carbon; in IV. and VII. are small quantities of chromite and silicates.

Analysis of schreibersite from IV. gave :—

Fe.	Ni.	Co.	P.	Cr.	Chromite.	S.	Total.
61·46	21·31	0·34	15·20	0·32	0·25	0·39	99·27

According to G. P. Merrill,\* Eakin's analyses of the meteorite of Hamblen County, Tennessee, showed that olivine could be present in only small quantities, for in the 37·63 per cent. of the stony portion which was soluble in hydrochloric acid only 1·34 per cent. of magnesia was present; and at the time no satisfactory conclusion was come to as to the mineral composition, beyond that the insoluble portion consisted mainly of pyroxene. Microscopical examination by the present author shows a holo-crystalline, granular ground mass of enstatite, diallage, and anorthite, with porphyritic pyroxenes and some indeterminable material between the grains. Olivine is inconspicuous, and cannot be separated. The anorthite gave the following results on analysis :—

SiO <sub>2</sub> .	Al <sub>2</sub> O <sub>3</sub> .	FeO.	CaO.	MgO.	Na <sub>2</sub> O.	Total.
42·02	37·77	trace	16·41	0·96	not determined	97·16

\* *Journal of the Chemical Society*, vol. lxxii. p. 58.

The enstatite was found to contain magnesium; but no calcium or aluminium. These minerals do not, however, altogether satisfy the requirements of the analysis of the soluble portion. After separating the anorthite as far as possible, some of the material is still gelatinized by acid, and as magnesium and calcium go into solution, the presence of monticellite is suggested. When the stony portion of the meteorite is boiled with water, chlorine, sulphuric acid, calcium, and iron are extracted; this suggests the presence of gypsum (derived from oldhamite) and lawrencite. The minerals probably present are then: nickel-iron enstatite, diallage, anorthite, olivine (or monticellite), oldhamite (or secondary gypsum), lawrencite, troilite, and schreibersite. The meteorite is to be classed as a mesosiderite; but the composition and structure are very variable, for the stony and metallic portions each in turn predominate in different parts. In the coarser portions, especially when near the metallic iron, there is a strongly marked cataclastic structure, which is well shown in the anorthite. The average specific gravity of the fragments is 4.32.

Melikof\* and Krijanowski have analysed a meteorite that fell in 1889 in the Kherson government, Russia. The analysis shows:—

	Per Cent.
Silica . . . . .	27.49
Lime . . . . .	2.11
Magnesia . . . . .	19.85
Ferrous oxide . . . . .	26.95
Manganous oxide . . . . .	0.66
Soda . . . . .	1.37
Potash . . . . .	0.17
Alumina . . . . .	1.62
Ferrous sulphide . . . . .	0.46
Ferro-nickel . . . . .	3.86
Ferro-chrome . . . . .	1.62
Phosphorus . . . . .	0.15
Free sulphur . . . . .	3.10
Sulphuric acid . . . . .	0.85
Di-thionic acid . . . . .	0.12
Amorphous carbon . . . . .	2.63
Hygroscopic moisture . . . . .	1.40
Organic matter and undetermined	6.11 †
Total . . . . .	<hr/> 100.00

The meteorite fall at Madrid on February 10, 1896, showed the presence of olivine, rhombic augite, maskelynite, nickel-iron, chromite, and troilite. It is worthy of note that no meteorite hitherto examined

\* *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xlv. p. 174,

† 5.51 in original.

has contained any substance which was not already known on the earth.\*

According to N. H. Winchell,† a meteoric iron was found in March 1894,  $2\frac{1}{2}$  miles north-east of Arlington, Sibley County, Minnesota. It is roughly heart-shaped, with an average thickness of one inch; weight  $19\frac{3}{4}$  lbs. The convex side is tolerably smooth, and has a spotted appearance, whilst the opposite, nearly plane surface is pitted and rough, some of the pits almost penetrating the specimen. Three structural directions brought out by etching are described in detail. Analysis by F. F. Sharpless gave :—

Fe.	Ni.	Co.	P.	Total.
90.781	8.605	1.023	0.045	100.454

Chromium, carbon, and combined carbon in traces were also found; sulphur, silicon, and manganese are absent. The composition does not appear to be uniform, as four determinations of the iron varied between 90.58 and 91.74; the carbon also varies.

G. W. Card ‡ describes the occurrence and classification of four New South Wales meteorites in the Sydney Museum. The Bingera, Cowra, and Temora meteorites are not only of very scarce types, but one, the Bingera, is almost unique. The last-mentioned meteorite belongs to the hexahedral division of Brezina, in which, on etching, a cubic structure and cleavage is revealed. The Cowra, Moonbi, and Temora meteorites belong to the octahedrite division. Photographs of the meteorites are appended to the paper.

**Manganese Ore in Huelva.**—C. Sundenheim § describes the manganese ore in Huelva, Andalusia, which occurs in lenses in Silurian clay slate, ranging from 70 to 1000 feet long, and up to 130 feet in thickness. The ores worked were chiefly pyrolusite and psilomelane between 1860 and 1890, and it was then discovered that the carbonate and silicates also occurred, and mining was resumed in 1894 on a more extensive scale. In 1895, 33,353 tons, of which about 1000 tons were oxide, were exported, whilst the amount in 1896 was about 90,000 tons, more than half of which goes to France. Two qualities are recognised for export, containing :—

Manganese.	Silica.
40 to 47	10 to 13
30 to 34	18 to 20

\* *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xiv. p. 190.

† *Journal of the Chemical Society*, vol. lxxii. p. 109.

‡ *Records of the Geological Survey of New South Wales*, vol. v. pp. 49-52.

§ *American Manufacturer*, vol. lx. p. 226.

**Manganese Ore in Georgia.**—W. M. Brewer\* states that the mining and shipping industry has been in operation over half a century. The author also describes the system of working.

**Manganese Ore in Colombia.**—E. J. Chibas† describes with numerous illustrations the work of railway building and mining manganese ore in the Republic of Colombia. The ore is found on the flanks of a steep mountain about 500 feet above and 2000 feet distant from the Nispero terminus. Tram-lines were laid along the face 25 to 50 or more feet apart, with a gradient of  $1\frac{1}{2}$  to 2 per cent., and the levels were connected by ore shoots built of planks and rough logs at an inclination of  $45^\circ$ . The ore was also brought down by an inclined plane to ore bins from which four railway trucks could be loaded at once.

In a further paper ‡ the author deals more in detail with the occurrence of the ore. An analysis is given as follows:—

MnO <sub>2</sub> .	Mn <sub>2</sub> O <sub>4</sub> .	SiO <sub>2</sub> .	FeO.	P.	Al <sub>2</sub> O <sub>3</sub> .	CaO.	MgO.	Cu <sub>2</sub> O.	H <sub>2</sub> O, &c.
16·98	59·30	18·77	0·90	0·031	0·12	0·98	0·30	0·09	3·02

The metallic manganese present amounts to 52 per cent., but picked samples range up to 63 per cent. The ore is found as pockets and boulders in the clay, which is sometimes locally washed away. Apparently serpentine underlies the deposit, and the ore is derived by solution from the igneous rocks of the locality, possibly in the Tertiary age.

**Chrome Iron Ore.**—Although chrome iron ore occurs at several places in California, yet there are but few places where it was worked in 1895 owing to the low price. An illustration is given of the San Luis Chrome Works. §

\* *Tradesman*, January 1, 1897.

† *Transactions of the American Society of Civil Engineers*, vol. xxxvi. pp. 65-85, with illustrations.

‡ *Transactions of the American Institute of Mining Engineers*, 1897, Chicago meeting (advance proof).

§ *Thirteenth Annual Report of the Californian State Mining Bureau*, 1896, pp. 48-50.

## II.—IRON ORE MINING.

**Mining in the Lake Superior District.**—H. V. Winchell \* states that in Minnesota the question is no longer one of supply for an increasing demand, but one of demand for the ore ready to be mined and marketed. The producing capacity is equal to the entire demand for Lake Superior ores, and yet the Mesabi district in 1896 produced less than three million tons, and the stocks have increased. The tendency everywhere is towards consolidation and union of interests between furnace men and mine operators, and some large combinations have been formed. One result is that the Oliver mine is the largest producer, with 808,291 tons as against 500,377 tons in the previous year. There is therefore a lessened tendency to open up new properties, although very considerable discoveries are being made almost every month. The author then refers to the three systems of working by steam-shovels, milling, and various underground systems, with square set, caving and slicing methods. A new system of working large rooms with roofs supported by saddle-shaped stulls set in solid ore at the sides promises to give excellent results at the Fayal mine.

At the Pewabic mine, in the Menominee range, much work was done in the past year in removing the pillars of the upper levels, and about 150,000 tons of ore have come from this source. By rooming and caving the ore is cleared out as the work progresses downwards. Much ore containing 40 per cent. of iron and 0·006 per cent. of phosphorus is now being worked in seams of 70 feet, and the pillars are then undercut and the whole mass let down. An output of as much as 15 tons per man per day has been attained.†

**The Lake Angeline Mines.**—J. E. Jopling ‡ describes the drainage of Lake Angeline by the three companies working ore under the lake and the handling of the mud during the mining operations. Chambers are worked out in the ore, and in the meantime the overburden is kept up by timbering, which is subsequently blasted down so as to let the surface fall in. Sand mixing with the timbers forms a strainer for the mud, draining out the water, after which the mud can be again brought in or caved down as each successive slice is undermined. Precautions

\* *Iron Trade Review*, vol. xxx. No. 1, pp. 7-9.

† *Iron Ore through the American Manufacturer*, vol. lix. p. 565.

‡ Paper read before the Civil Engineers' Association of Michigan, through the *Iron Trade Review*, vol. xxx. No. 5, p. 10.

are always taken to prevent the mud from running into other parts of the mine. At times this system has given trouble, but on the whole it is a success, and along the edge of the basin of mud a number of these caves or pits are now to be seen. When the basin is undermined the water that falls upon it must be taken care of by the pumps in the mines, while all water that can be dealt with at a higher level will be diverted. At present one man at each shaft attends to the pump, except at the time of heavy rains, and about 40 tons of coal are used monthly.

**Iron Ore Mining in Alabama.**—In a description of the haemaites of Alabama, H. M'Calley \* gives a short account of the workings of the upper bench of the Big seam at Spring Gap mines, between Birmingham and Bessemer. The part worked is  $8\frac{1}{2}$  feet in thickness, and is worked from an incline driven somewhat off the full dip so as to follow the joints. The incline is cut down into the lower layer so as to make a road with a clear height of 20 feet, or until large trucks holding four mine trucks of ore are low enough for them to be filled from the smaller ones in the headings. The large trucks are then hoisted by steam-power, and emptied by machinery into a crusher, from which the railway trucks are loaded.

**Prospecting for Iron Ore.**—C. Catlett † gives his experience with the use of the hand-augur for prospecting for iron ore, and strongly advocates its extended use. A full description is given of the appliances required, which chiefly consist of an augur and a chisel-bit, with lengthening rods and accessories for manipulating the tools and clearing the holes. Two men are employed for sinking each hole, and careful notes are made of the situation of each hole and of the ground passed through. Holes as deep as 80 feet may be sunk, but for depths of about 50 feet it appears that these appliances can be used most successfully. The time and cost for sinking a number of holes are given to show the advantages over trial shafts, and the author has employed this method with advantage in the iron ore deposits of the Potsdam in Virginia.

**The Preparation of Magnetic Maps.**—According to H. Sundholm,‡ it is more than thirty years since the method of exploring for

\* *Engineering and Mining Journal*, vol. lxiii. p. 44.

† *Transactions of the American Institute of Mining Engineers* (advance proof).

‡ *Teknisk Tidskrift*, vol. xxvi. pp. 44-46. Compare B. H. Brough's paper on the Exploration for Iron Ore with the Magnetic Needle, *Journal of the Iron and Steel Institute*, 1887, No. I. pp. 289-303.

iron ore with the magnetic needle, now in general use in Sweden, was first employed. In the preparation of magnetic maps it is desirable that a uniform method of colouring should be employed, and the author lays down a series of rules that should be followed in the preparation of such maps. A magnetic map of a deposit should consist of the following sheets :—(1) Title sheet; (2) surface plan; (3) geological map; (4) vertical intensity map; and (5) horizontal intensity map.

The exploration for magnetic iron ore is also described in the *Revista Minera*.\*

**Winding-Engines.**—An illustration is published of a winding-engine at the Wharton Iron Mine, near Hibernia, New Jersey.† It is rated at 450 horse-power. A cylinder 18 by 24 inches is mounted on each side of the drum on a heavy bed-plate, which drive it through a countershaft and spur gearing to give a speed of 800 feet per minute. The drum is cast in one piece,  $7\frac{1}{2}$  feet in diameter, with a grooved face of 6 feet.

**Mine Timber.**—W. Alvord ‡ estimates that from 1870 to 1891 no less than 674,765,000 cubic feet B.M. of timber and lumber, and 391,070,500 cubic feet of wood, representing a cost of over £9,200,000, have been used for the Comstock mines. About 200,000 acres of forest have been destroyed, and when the remaining 45,000 acres are denuded, wood will have to be brought over a hundred miles. Timber on the cleared spaces will require a century to attain the required size. Other details of timber consumption are also given.

**The Daimler Benzene Motor.**—The use of the Daimler benzene motor for mining purposes has made rapid progress in recent years. An account is published of its use in working an underground pump at the Maria Theresa iron ore mine in Hungary, where it gives satisfaction. A motor of this kind takes up very little room, is easily placed in position wherever required, and as readily removed when its use in that particular spot is no longer necessary. In collieries, and especially in fiery mines, its use might, however, be disastrous, as at present constructed, but some arrangement, similar to that in use for safety-lamps, might be introduced to prevent such danger. §

\* Vol. xlvi. p. 357.

† *Engineering and Mining Journal*, vol. lxiii. p. 163.

‡ *Proceedings of the American Forestry Association*, vol. x., through the *Engineering News*, vol. xxxvi. pp. 432, 434-435.

§ *Berg- und Hüttenmännische Zeitung*, vol. lvi. pp. 35-36.

**Electricity in Swedish Mines.**—In the Swedish iron mines electricity is being largely used as a motive power.\* The first long-distance installation in Sweden is at Grangesberg, the distance over which the power is transmitted being ten miles. At Hellsjon, where the turbines are situated, there are three dynamos, two of 150 and one of 100 horse-power. At these mines dynamite is manufactured, half the production being consumed on the spot.

**Measuring Ore Bodies.**—E. B. Kirby † deals with the sampling and measurement of ore bodies in mine examinations, chiefly in relation to deposits of the precious metals, but many of the points treated of can also be considered in connection with other deposits, such, for instance, as iron ore. The examination of a mining property necessitates an inquiry into everything which bears on its value as an investment. Amongst the principal facts to be determined are: the net value of the ore already discovered, the chances indicated for further discoveries, the best metallurgical treatment, and the past record of the property. Estimates are required of working expenses, costs of development, equipment, &c., together with the profit to be expected. The price and terms of payment, the working capital needed, and the time required for its recovery, the question of titles, the risks from litigation, flooding, and other accidents, also enter the problem, but the author only deals with the two points mentioned above. For sampling ore in place, four methods are in vogue—many small samples quickly taken from lines distributed at small intervals, large samples carefully taken from lines more widely distributed, mill runs, and panning tests. The first method is most economical in time and expense, but the second gives more accurate results. The distribution of the sample lines, the methods of taking the samples and of reducing them by mixing and cutting them in various ways, is then considered at length. Fixing the boundaries of workable ore is then fully dealt with by the aid of plans and sections of the veins, and the results of the values of the assayed samples.

**Handling Ore.**—Illustrations have been published ‡ of the plant being built at the Cleveland Docks for transferring ore from ships to railway trucks or on to stock piles. It consists of a travelling frame,

\* *Iron and Coal Trades Review*, vol. liv. p. 18.

† Paper read before the Colorado Scientific Society, through the Thirteenth Report of the Californian State Mining Bureau, 1896, pp. 679-700.

‡ *Marine Review*, through the *Iron Trade Review*, vol. xxx. No. 11, pp. 12-13.

with a number of cantilevers, on which run trolleys from which the buckets are suspended.

A table has been compiled by H. J. Slifer \* giving particulars of the ownership, size, and capacity of the various docks used for iron ore on the Great Lakes. Their total capacity is over 580,000 tons of ore.

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### III.—MECHANICAL PREPARATION.

**Magnetic Separation.**—H. B. C. Nitze † further ‡ describes the Wetherill magnetic concentrating process for substances of low magnetic permeability. Two principal types of apparatus are used. In one the magnets are horizontal, and the material is fed on to belts revolving over the pointed pole-pieces, and is delivered into the opening between them, where two shutters separate the non-magnetic and the magnetic particles. In the other type, the pole-pieces are inclined, and the material is fed on a belt below the poles. The magnetic material attracted to the poles is removed by belts travelling over them whilst the non-magnetic material falls away. The attraction of the feebly magnetic material is caused by the extremely condensed field, and this is produced by a current of low ampérage. The magnets are wound to give 918 ampère turns. Limonite and pyrolusite require 10 to 20 ampères, red haematite and garnet 4 to 8, and franklinite and siderite 1 to 4 ampères. Attempts have been made by different observers to determine the magnetic permeability, but their results do not agree altogether with those obtained by these machines. Some of the results with zinc, iron, and other ores are then given.

A description has been published of the latest form of magnetic separator for iron ore devised by J. Wenström. § This consists of a drum whose sides are provided with several magnets. The drum consists of a number of isolated iron bars arranged axially, and in such a way that there is always one pair of bars rendered magnetic by one pole of the magnet, while another pair is magnetised by the other pole. Larger pieces of ore come in contact with two bars, and are consequently more firmly held. The drum has a slight inclination, to allow the non-magnetic material to fall through more readily.

\* *Engineering News*, vol. xxxvii. p. 69.

† *Journal of the Franklin Institute*, vol. cxlii. pp. 279-292, with illustrations.

‡ See *Journal of the Iron and Steel Institute*, 1896, No. II. p. 290.

§ *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xlv. p. 40.

**Washing Iron Ores in Hungary.**—The ore lumps found at Morawitz and Dognatschka are separated at once where found.\* The material containing the ore in smaller particles is kept separately, and is taken to an ore-washing plant, where the waggons are tipped down an inclined plane serving as a charging plane for the drums in which the subsequent washing is to be effected. This inclined plane is kept constantly wet. Towards the bottom it takes a flatter angle, and here, by means of jets of water under some pressure, the ore mass gets thoroughly disintegrated, and in this state is run into conical drums without holes. Into this drum also a strong jet of water is forced. From the drum the stuff passes to a larger conical classifying drum perforated with holes 0·87 inch in diameter, at the lower end of which drum other jets of water are caused to play upon the ore mass under treatment. The mass passes on to a sheet-iron table, on which the ore lumps are separated by hand, whilst the waste passes to a lower storey of the building, and subsequently to the tip. The finer material which escapes through the holes in the drum passes to hand-jigs, about 15 or 20 being employed. The water required for the washing is delivered by a 30 horse-power engine. The washing begins in April and lasts until the middle of November, yielding monthly from 500 to 700 tons of washed ore, consisting largely of magnetite of excellent quality. The percentage of iron varies from 50 to 70, that of silica varying from 10 to 22. The yield of ore is about 21 to 25 per cent. of the material treated, the larger half being ore smalls, that is to say, less than 0·87 inch in diameter.

**Sampling Iron Ore.**—W. W. Taylor † describes the methods he used for sampling piles of jigged iron ore in which the lumps varied from the size of hickory-nuts down to sand. An iron pipe 2 inches in diameter and 13 feet long was driven into the pile 12 feet deep at intervals of ten feet. A head-piece was put on the pipe to prevent it splitting or upsetting. Two men using six-pound sledges could drive 25 holes daily. The pipe was withdrawn full of ore by a mule or by two men. With care the sample remained in the pipe even at an angle of 30°. The method might be applied under other circumstances.

\* *Berg- und Hüttenmännische Zeitung*, vol. lvi. pp. 53-54.

† *Engineering and Mining Journal*, vol. lxiii. p. 160.

## IV.—METALLURGICAL PREPARATION.

**Calcining Iron Ore.**—According to W. B. Phillips,\* while hydroscopic water may be expelled from limonite by heating it to 212° F., combined water is only expelled at a dull red heat. A gas-fired kiln is to be preferred, and the Davis-Colby kiln is advocated. As a rule, the size of the ore should be such that it will pass a 3-inch ring. Some particulars are given of the practice in Alabama.†

The brown haematite ores of the Borsod district of Austria-Hungary are subjected to calcination at the Witkowitz Steelworks in four Holz calciners. They are of the shaft type with gas-firing, and illustrations of them are published.‡ They are used for the lump ore, but the finer ore is roasted in Moser reverberatory furnaces with long sloping beds, with a roasting surface of 344 square feet. Each Holz shaft calciner will calcine in the twenty-four hours from 65 to 80 tons of ore, while each reverberatory will treat from 40 to 50 tons with a loss in calcining of from 18 to 20 per cent.

A. Ritter von Kerpely§ describes a gas ore-calciner at Rudobánya. The Triassic brown iron ores of Borsod County, Hungary, are in places very pure, but in others contain ankerite, ochre, and occasionally barytes and native copper. The following is an average analysis :—

	Raw Ore.	Calcined Ore.	
		Per Cent.	Per Cent.
Ferric oxide . . . .	68·57	70·30	
Manganous oxide . . . .	4·03	3·91	
Alumina . . . .	2·24	2·25	
Lime . . . .	1·40	1·15	
Magnesia . . . .	1·02	0·73	
Copper oxide . . . .	0·11	0·09	
Baryta . . . .	3·44	4·01	
Silica . . . .	10·10	10·72	
Phosphoric anhydride . . . .	0·06	0·07	

The above is the analysis of the ore after calcination in a calciner, of which drawings are given. Brown coal is used as fuel. Four such calciners treat the lump ore obtained from this district, the total output from which amounted in 1895 to 230,073 tons.

The charcoal blast-furnace at Gasvadia and the coke blast-furnace at Rescicza are also briefly described, and sectional elevations of these are given, as also of the coke blast-furnace at Tispolcz.

\* *Engineering and Mining Journal*, vol. lxiii. p. 183.

† *Iron-making in Alabama*, Alabama Geological Survey, 1896.

‡ *Stahl und Eisen*, vol. xvi. pp. 975-977, with three illustrations.

§ *Berg- und Hüttenmännische Zeitung*, vol. lv. p. 407, with illustrations.

## REFRACTORY MATERIALS.

**German Fireclays.**—The following are analyses of German clays used in the manufacture of firebricks shown at the Berlin Exhibition of 1896 : \*—

Material.	Silica.	Alumina.	Ferrio Oxide.	Melting-Point. Seger Cone.
	Per Cent.	Per Cent.	Per Cent.	No.
Baden clay . . . . .	54·43	39·04	2·78	33 to 34
Do. . . . .	57·47	35·45	2·98	32 to 33
Westerwald clay . . . . .	57·83	36·24	2·05	34
Do. . . . .	56·81	39·00	2·32	33
Do. . . . .	53·34	41·17	1·92	33
Do. . . . .	61·46	34·54	1·32	33 to 34
Do. . . . .	59·34	35·50	1·55	34 to 35
Do. . . . .	56·20	38·50	1·87	33
Kährlich clay . . . . .	52·66	41·62	3·04	34
Bendorf clay . . . . .	80·74	16·31	0·94	29
Weiherberg clay . . . . .	84·05	13·10	1·80	26 to 27
Mehlem clay . . . . .	77·97	18·04	1·08	31 to 32
Clay slate . . . . .	53·48	43·65	0·87	35 to 36
Do. . . . .	50·10	46·55	1·32	36

**Fireclay from Moravia.**—Fireclay of excellent quality is found in the neighbourhood of the village of Briesen in the Moravia-Trübau district. The clay occurs in beds between sandstones of Cretaceous age. It is largely used, amongst other uses, for firebricks and for crucibles for crucible steel manufacture. †

**Hungarian Fireclays.**—A. Kalecsinszky ‡ observes that the greater portion of the fireclay used in Hungary in furnace construction is still imported from abroad. The Royal Hungarian Geological Institute

\* *Stahl und Eisen*, vol. xvi. p. 723.

† *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xliv. p. 646.

‡ *Stahl und Eisen*, vol. xvi. p. 885.

has for a long time past collected samples of clays from all parts of the kingdom, and submitted these to examination, especially as regards their fire-resisting powers. For determining their relative value in this respect three kinds of furnaces are used. In the first, a temperature of 1000° C. is attained ; in the second, one of about 1200° ; and in the third, a temperature of about 1500°. In this last gas-furnace wrought iron soon melts. The clay to be examined is kneaded into shape and then heated in these furnaces, one after the other, and are subsequently classified by their relative infusibility under these conditions. In the geological section of the recent Buda-Pest Exhibition there was a collection of 600 clays which had been examined in this way, together with a map showing the localities where they were found. From this map it is seen that the fireclays are found in those districts in which felspathic rocks exist, such, for instance, as granite or trachyte. The farther away from such rocks is the spot where the clay is found, the worse are its fire-resisting properties.

**Russian Fireclays.**—J. Kowarsky \* observes that the whole district around Moscow is rich in fireclay, especially the Governments of Vladimir and Nijni-Novgorod. From this material the Kulebaki Works prepares firebricks by admixture with sand. Usually about equal quantities of sand and clay are taken, but the percentage of sand can be more or less according to the character of the clay. For bricks for use in regenerator chambers the mixture used is one-half clay, one-quarter sand, and one-quarter chamotte (burnt clay). For plugs, &c., a small quantity of graphite is added to the mixture. About 600,000 firebricks are made at this works annually. At the Perm cannon-foundry about a million firebricks are made, and at other works mentioned in the Urals a total annual production of about ten million bricks results. In South-West and South Russia there is a still larger out-turn, about twenty-five million firebricks being made annually. The material is of such excellent quality that the open-hearths often stand from 200 to 250 heats without repair, while a roof will hold out for two, three, or four campaigns. Some analyses mentioned show :—

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\* *Stahl und Eisen*, vol. xvi. pp. 917-918.

	Clay.	Chamotte from this Clay.	Kaolin.	Chamotte from this Kaolin.	Quarts from Krivoyrog.	Dnjeper Sand.
Sand . . .	6·14	...	14·20	...	...	...
Silica . . .	52·90	60·50	46·70	54·20	97·9	97·9
Ferric oxide . . .	0·80	0·90	0·80	0·90	0·9	1·2
Alumina . . .	33·40	38·00	37·30	43·20	0·8	0·5
Lime . . .	0·31	0·37	1·00	1·10	0·3	0·3
Magnesia . . .	0·06	0·07	0·01	0·06	...	...
Loss on ignition . . .	12·00	...	14·10	...	...	...
Corresponding number of the Seger scale . . .	35	...	36	...	...	...

The kaolin mentioned in the above analysis shows a similar composition to the well-known Zettlitz fireclays.

Amongst fire-resisting material, chrome ore must also be mentioned, but this, the author observes, cannot compare in quality with the imported magnetite. The kingdom of Poland and the Northern St. Petersburg district are poor in fireclay deposits.

**Fireclay in Indiana.**—In the twentieth Annual Report of the Department of Geology and Natural Resources of Indiana, W. S. Blatchley publishes an interesting account of the clay industries of the coalfields of the State. Most of the beds are interstratified with coal, sandstone, and shale, and they are often of excellent quality. The total value of the clay products of Indiana amounts to £226,732 annually.

**The Composition of Firebricks.**—It is urged by Heintz\* that firebricks, and especially such as are to be used in blast-furnace and coke-oven plants, should be compelled to have a composition varying within agreed limits as to the different components.

He points out that pure aluminium silicate,  $\text{Al}_2\text{O}_3 \cdot 2\text{SiO}_2$ , contains 46·1 per cent. of alumina and 53·9 per cent. of silica. It has become the custom in the past decade to guarantee a minimum percentage of  $\text{Al}_2\text{O}_3 + \text{SiO}_2$ , and a maximum percentage of fluxing constituents and of free silica. If firebricks were homogeneous throughout, it would be a different matter, but this is unfortunately not the case. It is true that firebricks may be manufactured which are approximately homogeneous in composition—say, for instance, from a good kaolin—but such bricks are rarely, if ever, made. As a rule, the binding material is homogeneous

\* Paper read before the Verein Deutscher Fabriken Feuerfester Produkte; *Stahl und Eisen*, vol. xvii. pp. 63-64.

in character, as is the mass of the brick itself. In highly aluminous bricks the main mass is usually much higher in alumina than is the binding agent used, and it may consequently result from this difference that in practice a less highly aluminous brick may stand better than another higher in alumina. The author refers, too, to the contraction which bricks exhibit on being raised to high temperatures, and mentions a case in which bricks made of French dracelite, and containing 83·7 per cent of silica and 60·4 of alumina, the remainder being mainly ferric oxide, contracted several per cent. on being exposed for a few days to the temperature of the melting-points of from Nos. 17 to 18 of the Seger scale, notwithstanding that the bricks had appeared fairly well-burnt. The author compares a brick with a mass of material consisting partly of wrought iron and partly of cast iron, and asks how an ordinary percentage analysis would show the quality of the material. The author exhibited bricks containing 45·9 per cent. of alumina, 52 of silica, 1 of ferric oxide, and 2 of other fluxes. These possessed a crushing strength of about 3000 lbs. per square inch, and withstood a bending stress of 1294 lbs. per square inch.

**The Colours of Firebricks.**—C. Ferry \* discusses the colours of firebricks, which are generally white, brown, or red, with intermediate shades. White bricks are produced by burning pure fireclay with an oxidising flame. In these circumstances all the coal is burnt completely, and higher temperatures result, with the production of a thoroughly well-burnt and therefore solid brick. A brownish stain is often considered desirable, as showing that the brick has been well burnt, and this is explained by the absorption of carbonaceous matter from the products of combustion in the reducing flame, and the subsequent partial fritting at high temperatures, which causes it to be retained. The oxidising flame will, however, give as good bricks without this coloration. The red colour is due to iron when the bricks are burnt in an oxidising atmosphere, but it is not produced, or is disguised, by the organic brown stain from the reducing flame, so that the presence of iron is not apparent.

**Bauxite.**—According to W. M. Brewer,† the mining of bauxite in 1896 has been carried on by the same companies that have been engaged in it since 1891 in the States of Georgia and Alabama, but only 15,000

\* *Iron Age*, vol. lix. No. 6, pp. 5-6.

† *Engineering and Mining Journal*, vol. lxiii. p. 17.

tons have been produced in 1896—a decrease of 3000 tons on the previous year. Various forms of kilns are now adopted for drying the ore to replace simple air-drying, and one company has adopted a kind of log-washer, by which it has successfully treated material from the waste heaps.

A. Liebrich \* points out that bauxite occurs in the younger rocks, whilst emery occurs in the oldest (gneisses, &c.); and that in their chemical composition the only important differences are the much larger amount of water in bauxite, and the presence of ferrous oxide (in the magnetite) in emery. Analyses of bauxite, calculated without the water, compare very closely with analyses of emery. This similarity of composition suggests that the two minerals may have the same origin; bauxite has been derived from silicates by decomposition, and the same must be true for emery, which has been brought into the present state by the action of water under pressure and at a high temperature.

\* *Journal of the Chemical Society*, vol. lxxii. p. 104.

# F U E L.

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### I.—CALORIFIC VALUE.

**Calorific Power of Coal.**—In a lengthy paper on comparative tests of steam-boilers with different kinds of coal, by C. E. Emery,\* the subject of the calorific value of coal is very fully discussed, and the numerical and other results obtained by many observers are given in considerable detail. It is concluded that practical evaporations are not accurately proportioned to the calorific values shown by the calorimeter or chemical composition, but they can be compared with a fair degree of accuracy by stating the results in units of evaporation per pound of combustible. Some ten tables are given to show calorific values, analyses, and evaporative tests.

N. W. Lord and F. Haas † give the results of a number of experiments made on the calorific value of various American coals as determined by the Mahler calorimeter, and at the same time they give an account of the chemical work necessary to obtain the composition. The coal was carefully sampled by quartering and finely powdering. The sample was compressed in a screw press to a coherent briquette weighing a gramme, and burnt with an oxygen pressure of 16 to 17 atmospheres. The residue in the bomb was used for determining the sulphur. The

\* *Transactions of the American Society of Mechanical Engineers*, vol. xvii. pp. 237-292.

† *Transactions of the American Institute of Mining Engineers*, 1897; Chicago meeting (advance proof).

table below shows the analyses and the results obtained by the calorimeter, those derived from Dulong's formula—

$$\text{Calorific power} = 8080 \text{ C} + 34,462 (\text{H} - \frac{1}{8} \text{O}) + 2250 \text{ S},$$

being given for comparison. There is a remarkable coincidence between the figures thus obtained and the observed results :—

	C.	H.	O.	N.	S.	Ash.	Mois-ture.	Volatile Matter.	Fixed Carbon.
I. . .	72.65	5.06	8.95	1.34	2.89	9.10	1.93	87.35	51.63
II. . .	75.24	5.18	8.24	1.51	1.79	8.02	1.37	86.80	53.81
III. . .	75.19	5.14	9.05	1.46	1.98	7.18	1.81	86.32	54.69
IV. . .	68.03	5.29	15.64	1.44	1.59	8.00	6.59	35.77	49.64
V. . .	78.65	5.17	7.22	1.41	1.28	6.27	1.38	36.68	56.67
VI. . .	84.87	4.29	3.51	0.85	0.59	5.89	0.76	18.51	74.84

		Calorimeter.	Dulong.
I. . .	{ Upper Free Port coal, Ohio and Pennsylvania	7293	7292
II. . .	{ Pittsburgh coal, Pennsylvania	7532	7550
III. . .	{ Middle Kittanning coal, Darlington, Pennsylvania	7494	7502
IV. . .	{ Middle Kittanning coal, Hocking Valley, Ohio	6663	6683
V. . .	{ Thacker coal, West Virginia	7817	7853
VI. . .	Pocahontas coal	8176	8198

The calorific values calculated from the fixed carbon only do not give results with sufficient accuracy. The inquiry was pushed in another direction, with the following results, as stated by the authors :—"The results of our tests seem to indicate the interesting conclusion that the character of a coal-seam, as far as its fuel value is concerned, is a nearly constant quantity over considerable areas. The determination of the value for seams would be of great use, as the rapid proximate analysis, or, for that matter, merely the determination of ash and moisture in low sulphur coals, would be sufficient to grade coals of the same vein."

**Pyrometry.**—Professor W. C. Roberts-Austen \* discusses the industrial uses of the recording pyrometer, which, up to the present time, has chiefly been used for research work, but it has had many practical applications, and there is a growing field for it. It has been somewhat extensively used for regulating the temperature of hot-blast stoves at

\* *Journal of the Society of Chemical Industry*, vol. xvi. pp. 5-9.

blast-furnaces. For this purpose the thermo-couple is placed in the horseshoe blast-pipe round the furnace, and the wires are led to a recording instrument placed in any convenient locality. If the stoves worked regularly and were changed properly, the instrument showed a curve like the teeth of a saw, the temperature rising suddenly to say 1600° Fahr. when a new stove was put on, and falling gradually to 1100° Fahr. during an hour, when the next stove came into work. Sometimes, however, the curve showed irregular teeth unequally spaced, and from these it was easy to see whether any particular stove was being overheated, and whether the workmen were attending properly to their duties.

R. C. Styles, who has had a considerable practical knowledge of the instrument, gave an account of his experiences. In one instance the record showed the absence of the foreman, and his neglect to change the stoves. Irregularities in the curves in several instances led to investigations that would otherwise never have been made, as, in the ordinary course of affairs, it was assumed that the stoves were working properly. A leakage of hot air from one stove to another, and the omission of the top courses in a stove, were examples of defects thus brought to light. The appliance was also used in the downcomer, and the movements of the bell when charging were made very clearly visible, and the change of defective tuyeres was also shown. As an average in everyday use the thermo-couple lasted two or three months, and it was an inexpensive matter to replace them, whilst during their life they endured practically no change, so that their indications were unaffected.

The fourth report by W. C. Roberts-Austen \* to the Alloys Research Committee refers to certain experiments, the results of which have improved the recording pyrometer, and have rendered its calibration more accurate. For very delicate work, only part of the current from the thermo-junction is allowed to pass through a specially built galvanometer, and a water-clock is used to control the motion of the photographic plate. Careful calibrations of a thermo-junction with an air pyrometer have also been made.

Further particulars have appeared † of the Uehling-Steinbart air pyrometer ‡ which was first used at one furnace of the Gloss Iron and Steel Company in February 1894, and has since been applied at several blast-furnaces at Pittsburgh for determining the blast temperatures.

\* *Proceedings of the Institution of Mechanical Engineers*, 1897 (advance proof).

† *Iron Age*, vol. lviii. pp. 814-815.

‡ *Journal of the Iron and Steel Institute*, 1896, No. I. p. 332.

W. Kent gives some of the autographic records obtained with this instrument, to show the variations observed in the temperature, and gives an account of the causes to which they are ascribed. A portable form of the appliance is now being made.

H. von Jüptner \* describes Wiborg's thermophone,† and gives tables connected with its use in practice. While, he adds, it must be admitted that the thermophone under certain conditions cannot give an absolutely correct value, still, even under such circumstances, it shows the relative temperature variations with much exactness, and forms the most simple and useful method for the determination of high temperatures that as yet exists. Temperatures varying from 300° C. upwards to about 2500° C. can be measured, and, as a general rule, with much accuracy.

L. Holborn ‡ discusses the Le Chatelier pyrometer, and describes its use. Investigations carried out by himself and W. Wien have shown that this pyrometer is accurate to  $\pm 5^\circ$  C. at 1000° C. It can be used up to 1700°, and, on the other hand, down to ordinary temperatures. Below 200°, however, an ordinary thermometer is better. In using this pyrometer, the chief points to observe are to keep the wires well isolated from each other and well protected from the action of the hot gases. The first point can be effected by the use of an unglazed clay or porcelain tube, but for the second it is necessary to enclose the whole in a glazed tube to prevent the gases attacking the wires, as they would alter the thermo-electric intensity of the couple, and at high temperatures gradually destroy the platinum. A momentary contact, such as would result from the fracture of the protecting tube, is, however, not dangerous. Annealing in air restores the electro character of the couple after such an accident. This is the chief advantage of this pyrometer as compared with the resistance pyrometer, for in that one a single accident resulting from contact with the hot gases will lastingly change the resistance of the platinum of the wires.

The material to be used for the protecting tube is next considered, and then attention is devoted to the galvanometer to be employed, together with the conditions affecting its use when used at the Imperial Testing Laboratories at Charlottenburg as made by Messrs. Keiser and Schmidt of Berlin. Should it not be possible to prevent the galvanometer from becoming heated, the readings show values that are too low. In that case the readings should be multiplied in the case of the

\* *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xliv. pp. 99-104.

† *Journal of the Iron and Steel Institute*, 1896, No. II. p. 296.

‡ *Zeitschrift des Vereines deutscher Ingenieure*, vol. xxxi. pp. 226-227.

galvanometer mentioned by  $(1 + 0.0013t)$ , if the instrument is heated  $t$  degrees above the temperature of the room.

Experiments have been made at the Physikalisch-Technische Reichsanstalt \* in connection with pyrometers for the determination of high temperatures. With regard to the question of fireclay appliances, it was found that an air pyrometer could be produced which would give adequately satisfactory results up to temperatures of about  $1700^{\circ}$  by using a fireclay vessel made of the material which is employed at the Royal Porcelain works, burnt at a temperature of about  $1700^{\circ}$ .

If a pyrometer is to be of any regular use in works, it should be provided with a temperature scale which any workman can read off. Further, its readings must not be altered by the action of high temperatures, and it must be fairly durable. The best results in these respects were shown by the Le Chatelier pyrometer as modified by Holborn and Wien.

**A High-Temperature Furnace.**—H. L. Gantt † suggests a form of furnace to obtain a temperature of  $6000^{\circ}$  F. It consists of a shaft furnace, fed with coke and hot blast from regenerators, which are supplied with hot air when being heated by burning the products of combustion from the furnace. The applications of such a furnace to the manufacture of calcium carbide and cyanides are described. J. W. Richards is of the opinion that only a water-jacketed furnace could stand such extreme temperatures, and that by calculating from the specific heats of the products of combustion, a temperature of  $3470^{\circ}$  C. might be obtained with blast heated to  $2500^{\circ}$  C.

## II.—COAL.

**Coal in Kent.**—F. Brady, G. P. Simpson, and N. R. Griffith ‡ give some particulars of the bore-hole in the Great Fall at the foot of Shakespeare Cliff. The seams of coal above a foot in thickness are ten in number, and are respectively  $2\frac{1}{2}$ , 2, 2,  $1\frac{1}{4}$ , 1,  $2\frac{1}{2}$ ,  $2\frac{1}{4}$ ,  $2\frac{3}{4}$ ,  $1\frac{1}{2}$ , and 4 feet in thickness. The depth from the surface to the top of the Coal Measures is 1157 feet, and the bore-hole then passes through 1173 feet of these measures. In seams from 2 up to 4 feet there are 18 feet of

\* *Stahl und Eisen*, vol. xvi. p. 840.

† *Journal of the Franklin Institute*, vol. cxlii. pp. 458–469.

‡ *Transactions of the Federated Institution of Mining Engineers*, vol. xi. pp. 540–551.

coal which may fairly be considered workable. The beds at present found appear to belong to the upper region of the Middle Coal Measures. A shaft 17 feet in diameter in the clear, and a second shaft 20 feet 120 feet distant, are now being sunk. A detailed section of the boring is given, and also particulars of the fossils found as identified by R. Zeiller.

**Eastern Extension of the Midland Coalfield.**—G. Dunston \* describes the eastern extension of the Midland coalfield as shown by the diamond-boring at Southcar, on the borders of the north of Lincolnshire. Soundings made at the point called Coal Pit in the North Sea, and practically on the same latitude as Barnsley, always showed coal, so it was concluded that this might be the under-sea outcrop of the Yorkshire and Derbyshire field. The boring, after passing through part of the Trias and the whole of the Permian formation, entered the Coal Measures at a depth of 1700 feet. A detailed section of the strata is given. The following details are extracted to show the seams passed through and their depths :—

	Thickness.	Depth from Surface.	
		Ft.	In.
Coal . . . . .	1 2	1833	2
Coal . . . . .	0 5	1856	7
Coal . . . . .	0 10	1879	8
Shafton seam . . . . .	3 1	1926	6
Coal . . . . .	0 8	1976	2
Bagsshaw seam . . . . .	1 7	2199	6
Swinton Pottery seam . . . . .	3 9	2397	1
Coal . . . . .	1 3	2472	1
Coal . . . . .	0 10	2594	5
Wathwood coal-seam . . . . .	0 11	2621	0
Two-foot seam . . . . .	0 10	2668	6
Abdy or Winter seam . . . . .	1 0	2709	11
Low Beamshaw seam . . . . .	1 0	2849	5
Kents thick seam . . . . .	4 5	3012	7
Barnsley soft coal-seam . . . . .	4 9	3142	9
Barnsley hard coal-seam . . . . .	4 7	3185	7

W. S. Gresley † gives some sketches of some interesting Coal Measure sections in the Leicester and South Derbyshire coalfield, taken from some fireclay workings in those districts. These show gashes and curious distortions in small coal-seams with the strata immediately underneath, and the author ascribes their production to the action of ice, probably during the Glacial period.

\* *Transactions of the Federated Institution of Mining Engineers*, vol. xii. pp. 515-524.

† *Transactions of the Manchester Geological Society*, vol. xxv. pp. 95-104, with illustrations.

**Coal in Lanarkshire.**—J. Prentice \* describes the mineral seams which have been or are being worked in the parish of New Monkland, in the extreme north-eastern corner of Lanarkshire, and covering some twenty thousand acres. The history and geology of the district are briefly sketched, and a description of the following coal-seams in descending order is given:—Upper coal-seam, Ell coal-seam, Pyotshaw and Main coal-seams, Humph coal-seam, Splint coal-seam, Virgin coal-seam, Musselband coal-seam, Blackband ironstone, Soft ironstone, Virtue-well coal-seam, Lady Grange coal-seam, Musselband ironstone and shale, Kiltongue coal-seam, Lime coal-seam, Upper Drumgray coal-seam, Lower Drumgray coal-seam, Slatyband ironstone, and the Glenboig fireclay seam. The present output is not likely to be exceeded, and in a few years the seams will be worked out. Then recourse will have to be had to the Lower Coal Measures, which lie at a very considerable depth over a great part of the area, but in parts they may occur at a depth of 900 feet.

**Coalfields of France.**—J. Bergeron † discusses the possible extension of the coalfields of France, and bases his arguments on the broad principle that ancient lines of elevation have often been followed by recurrent upheavals and depressions, and that a study of the surface rocks will often give a clue to the configuration of the older formations which lie beneath. After generally referring to the three European mountain systems, the Caledonian, Hercynian, and Alpine, attention is particularly directed to the second of these, and its connection with the districts of the Ardennes, Brittany, the Central Plateau, and the Vosges. These are then dealt with in detail, and on a map are marked such synclinals as are known to be filled with Carboniferous deposits, from which the probability of further extensions is discussed.

From inquiries made at Calais, it appears that since the discovery at Dover as many as a dozen borings, some to a depth of 2000 feet, have been sunk within a radius of twenty miles of Calais without succeeding in finding the coal-path which crosses from Belgium in the direction of England. This, it is now confidently believed, has been struck at a village on the sea-coast near Blancnel, where one of three borings between there and Calais has been in course of sinking during the past twelve months. The authorities are reticent, but it is stated that coal was struck at a depth of 300 yards, the seam being about 2 feet

\* *Transactions of the Federated Institution of Mining Engineers*, vol. xii. pp. 435–450.

† *Ibid.*, pp. 385–360, with maps.

thick. From the geological evidences obtained, it is believed that the path of the Coal Measures will be found to run from between Calais and Boulogne, and to test this another boring is to be at once started at Cape Grisnez.\*

**Coalfields of Bohemia.**—With the exception of a monograph published in 1861 by the Austrian Geological Survey, no detailed description has hitherto been published of the Bohemian coalfields. J. Jaroschka † has therefore been induced to publish the results of his observations during twenty-four years' experience in the Kladno, Schlan, and Rakonitz coal region. The memoir, which covers 93 pages, and is illustrated with two plates, contains a detailed account of the history, geology, and present development of this coalfield, which supplies 22 per cent. of the coal output of Austria.

**Coal in Dalmatia.**—According to A. Rebol,‡ in the Ruda basin, north of Sinj, there exist recent strata of considerable thickness overlying the Chalk, and dipping 60°. Some explorations for coal in the Ruda basin show the coal-seam to be 4 feet in thickness; but it is intercalated with limestone, so that only from 65 to 75 per cent. of saleable coal can be obtained. Overlying this seam are measures containing a few coal-bands, overlain in turn by a seam of good coal only  $4\frac{1}{2}$  inches in thickness, but which increases to  $6\frac{1}{2}$  feet at the outcrop. The Ruda coal is of the best quality known in Dalmatia, being suitable for gas-making.

**Analyses of Brown Coal.**—G. Hottensauer § publishes the following analyses of brown coal:—

	Zenica, Bosnia.	Majevica, Bosnia.	Monte- negro.	Nagy- Kovacay.	Britz.
Carbon . . . .	Per Cent. 53·45	Per Cent. 66·54	Per Cent. 58·97	Per Cent. 46·64	Per Cent. 63·27
Hydrogen . . . .	3·64	4·45	3·35	3·75	4·91
Oxygen and nitrogen . . . .	19·09	15·96	16·88	18·56	18·97
Sulphur as sulphate . . . .	0·70	1·16	0·59	0·06	...
Sulphur, combustible . . . .	2·69	4·58	0·56	6·28	...
Ash . . . .	10·13	11·60	4·70	15·06	1·45
Water . . . .	13·69	1·45	15·65	16·00	11·25
Yield of coke, ash-free . . . .	38·91	44·90	41·70	34·90	42·20

\* *Daily News*, March 2, 1897.

† *Jahrbuch der k.k. Bergakademien*, vol. xliv. pp. 183-226.

‡ *Montan Zeitung*, January 1, 1897.

§ *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xliv. p. 659.

**The Coalfields of Bulgaria and Servia.**—Many coalfields are now in operation in Servia and Bulgaria.\* In Bulgaria coal has so far been found in about twenty or twenty-two places. The most important of these coal-basins are those of Mochino and Pernik, forming the westerly portion of a Tertiary basin in the immediate neighbourhood of the capital. It is brown coal that is mined at Pernik, an assay showing :—

Fixed Carbon.	Volatile Matter.	Ash.	Moisture.	Sulphur.	Calories.
41.91	35.073	8.74	12.471	1.86	4,594

This coal-mining is carried on by the State itself.

The largest portion of the coal districts of Servia lies on the Danube, below the Falls. The chief coal-mining centre is Poscharewitz. At Dobra coal is found which shows on assay :—

Carbon.	Water.	Ash.	Coke.
76.45	2.78	2.67	68.33

A true bituminous coal of excellent quality is found near Tschuprija. This is stated to yield 92 per cent. of coke, but this is apparently an error.

**The Westphalian Coalfield.**—A. Kowatsch † gives a short description of the Westphalian coalfield, which extends from the Rhine to Osnabrück in Hanover. Coal is found at a depth of 600 to 2100 feet. The formation is folded several times, and there are four important seams, but altogether there are about one hundred seams divided into three groups. The lowest consists of twenty seams with 35 feet of workable coal, the middle with forty seams and 96 feet, and the upper with forty seams and 97 feet. Five kinds of coal are distinguished, ranging from semi-anthracite to long flaming coal, and five sizes are made for the market, and a few details are given as to their preparation.

Robiaud ‡ gives the results of his observations made during a tour in the Westphalian coalfield.

In 1896 bore-holes for coal were commenced at Sinsen, near Recklinghausen, on the northern edge of the Westphalian coalfields. Bore-holes close to each other were put down by different parties, and as the first discovery was therefore a matter of the greatest importance, there was keen rivalry in the progress of the bore-holes. One set were employing the process used by Messrs. Winter of Camen, and the other

\* *Berg- und Hüttenmännische Zeitung*, vol. lv. p. 298.

† *Engineering and Mining Journal*, vol. lxii. p. 585.

‡ *Bulletin de la Société de l'Industrie Minérale*, vol. x. p. 241.

were adopting the method patented by Raky. The former method was that of a dry free-fall, while the latter adopts water-cleaning and a spring-equalisation of the weight. This Raky system proved considerably the more rapid. Details are given as to the comparative progress made by the two methods in this instance.\*

**The Coalfields of Upper Silesia.**—F. G. Bremme † observes that the Upper Silesian coalfield is a portion of the basin of Poland, Austria, and Upper Silesia, which has an area of 5600 square kilometres, 600 of which are in Russian Poland, 1000 belong to the Ostrau-Karwin district of Austria, while of the remaining 4000 a portion passes across the south-eastern boundary of the Oppeln district of Prussia.

The productive coal region stretches northwards to the vicinity of the town of Tarnowitz, to the west to Ratibor, and beyond on the left bank of the Oder. In its south-western division the coalfield is partially covered by Tertiary beds, while from the north to one part of its southern boundary it is covered by Trias. A portion of this—the Muschelkalk—contains the noted zinc and lead deposits of Upper Silesia, and also the only iron ore deposit there which is of importance.

The coal-seams of Upper Silesia are of great average thickness. Indeed, so much is this the case, that seams of from 3 to 5 feet in thickness are frequently not mined at all. The average thickness of the seams mined varies from 10 to 23 feet. By no means rarely, however, the seams mined are from 29 to 39 feet in thickness. Synclinals too exist, in which a great number of seams have been raised and are of great thickness and purity, thus affording a considerable additional facility to their being mined, the coal being found at shallow depths.

With regard to the character of the coals mined in the Central district of Upper Silesia, the first point noticeable about them is their purity. The ash contents is usually so low that wet preparation can be almost entirely done without. The percentage of sulphur is usually less than 1. Unfortunately most of the coals mined are not caking. They are long-flame non-caking coals, which, while excellent for heating or steam-raising purposes, are quite useless for coking. Indeed, only a very small proportion of the coal found at all approaches caking coal in character. In general the rule holds that the caking properties of the seams diminish from the floor to the roof, and from the west to the east in the Zabrze-Myslowitz seams.

The seams mined at the Königin Luise Colliery, at the extreme western

\* *Stahl und Eisen*, vol. xvii. p. 286.

† *Ibid.*, vol. xvi. p. 755.

limit of the group of seams, yield the best caking coal produced in Upper Silesia. Of the total quantity of coal mined in 1895 in this district, in round numbers about eighteen million tons, scarcely two million are capable of use in the manufacture of coke. The following is an analysis of a sample of the very best caking coal mined in Upper Silesia:—

Carbon.	Hydrogen.	Oxygen.	Nitrogen.	Sulphur.	Ash.
79·57	5·01	9·48	1·10	0·80	4·84

A crucible assay yielded 72·55 per cent. of coke.

Of the 1,580,000 tons of caking coal which were converted into coke in 1895, about 950,000 tons were derived from the Königin Luise Colliery. The author names the other chief producing collieries with their approximate respective outputs.

The coal of average quality coked yields in the coke-oven about 59 per cent. of lump, 4 of nut, 4 of smalls, and 5 of fines. The lump coke is employed solely for blast-furnace purposes, whilst the rest is sold to the zinc-works. The coke made in Lower Silesia, Westphalia, and the Ostrau district is more suitable for foundry use than that produced in Upper Silesia. By far the larger portion of the coke produced is made in ovens from which the by-products are collected, the chief type being the Otto-Hoffmann. Of these there are 720 in use and 150 building. They treat about 700,000 tons of coal a year. Other varieties of ovens arranged for the collection of the by-products which are in use are those of Appolt, Collin (vertical), Winzek, Dilla, and Frit. The total quantity of coke made in Upper Silesia in 1895 amounted to 938,000 tons of lumps, nuts, and smalls, and 84,000 tons of fines. The Upper Silesia blast-furnaces consumed 712,000 tons of this coke.

According to C. Gaebler,\* the Upper Silesian coalfield forms a single large basin extending over an area of 2016 square miles, the larger portion belonging to the Prussian province of Silesia, a small portion in the south and east to Austria, and the smallest portion of all in Russian-Poland. The Coal Measures are deposited on Lower Carboniferous and Devonian strata. The various divisions of the Upper Silesian Coal Measures show such great variations that it is impossible to estimate the thickness of the whole series. The lower division, which is worked in the extreme south-west and north-east of the coalfield, has, near Ostrau and Rybnik, a thickness of 4483 yards, with 69 yards of coal in sixty-one workable seams, while the thickness in the north-east, near Golenog, is only 546 yards, with 7½ yards of coal in five workable seams.

\* *Zeitschrift für praktische Geologie*, 1896, p. 457.

**The Coalfield of the Wurm District.**—This coalfield, on the Prussian-Holland frontier, is divided by a fault into two sections.\* In the western half the less caking coals occur. For seven hundred and eighty years mining has been continuous in this section of the field. The eastern half of the field contains caking coal. The fault has thrown the seams down some 200 to 400 yards. Numerous seams occur in this half of the field which are not found in the other. The various colliery companies working in this district are named, and a sketch map of the district is also given. A new shaft is now being sunk to a considerable depth, and of large dimensions, with a view to open up a considerable portion of the field, which is as yet unworked. Some £200,000 is to be spent on this shaft, and on opening out the ground in connection with it. It will be a curious fact that numerous classes of coal, from anthracite to non-caking steam-coals, will be raised through this one shaft.

**Coal in Hungary.**—According to A. Sasvari,† with the exception of peat, the most recent occurrences of fuel are found in the lignite beds which occur in the Congerian beds of Pliocene age, in Transylvania, Croatia, and Slavonia. The Miocene age is, however, much more important, as in the Mediterranean beds are found the almost inexhaustible beds of salt and coal. Of the latter, the principal occurrences are at Salgó Tarján (Neógrád), Diós Gyór (Borsod), Hidas (Baranya), and Brennberg (Sopron). The Oligocene age contains in the upper series several beds of coal thick enough to work, and the Eocene period includes thick and important seams at Dorogh, Tokod, Sárisáp, Csölnök, Nagykovacs, and Szt. Iván.

Formations of Mesozoic age cover the most extensive areas in Hungary, and contain some important deposits of coal. Between Pécs and Nadas, in a distance of some twenty miles, a coal-bearing formation is found consisting of marly shales, sandstones, and coal-seams, and belonging to the Upper Trias. In the southern part as many as seventy seams are found, of which twenty-five are workable. The thickness of these beds is about 930 yards, and the length of the basin is six or seven miles, with a breadth of one to one and a quarter mile. The Upper Chalk contains some coal-seams of considerable extent in the neighbourhood of Ajka, and also at Homok-Bödöge, north of Bakony. At Ajka there are twenty-five seams, but only two are thick enough to mine.

\* *Berg- und Hüttenmännische Zeitung*, vol. iv. pp. 161-163.

† "Catalogue Général de l'Exposition Nationale des Millénaire, Budapest," 1896; *Colliery Guardian*, Dec. 11.

The coal-seams at Doman, Stájerlak, Faczamare, and Berzanszka apparently belong to the Lower Lias, but at the latter place this classification is still open to discussion. The Palæozoic strata are greatly restricted in this country, but coal formations of this age are found over a fairly large area in the Western Carpathians. In the Banat there are several workable deposits, such as the four beds at Szekul, near Resicza, and four at Eibenthal.

Hungarian coal-mining is not of ancient date, for the earliest discovery does not reach farther back than the year 1750, when a peasant accidentally set fire to an outcrop on a hill near Sopron. In consequence it was named Brennberg or burning mountain. The use made of this coal was, however, very small. In 1800 less than 4000 tons was worked, but this rose to 33,600 tons in 1894. It was not until 1830 that the coal industry assumed dimensions of any importance, but in that year a company was formed for steam-navigation on the Danube, and on this account the coal at Pécs and the lignites at Esztergom were worked. These mines produced 2184 tons in 1854 and 275,000 tons in 1894. The greatest increase in the total production of the country dates from 1866, at which time the output was 350,000 tons. The collieries now working, such as those at Resicza-Anina, Berszászka; Baglyasalja and Salgó-Tarján, in the county of Neógrád; Diós Gyór and Ozd, in Borsod; Pécs and Szaszvar, in Baranya; Ajka, in Veszprem; Dorogh, Tokod, and Annavölgy, in Esztergom, and others, are constantly developing, and opening up new workings. To this list may be added the mines at Petrozseny and Urikany, in Transylvania and Kalnik; Krapina and Vrdnik, in Croatia.

A new discovery of coal in Hungary is reported by T. von Majanovic.\*

**The Doman and Szekul Collieries†—**These are situated near Reschitzta, in Hungary. At the Doman Colliery two Liassic seams are mined, separated from each other by from 50 to 70 yards of sandstone. The upper seam, in its chief parts, consists of two benches, 1 and  $1\frac{1}{2}$  yard thick respectively. The second seam reaches a thickness exceeding three yards. Two other seams are also mined. Three shafts are now in operation, two of which are winding-shafts, whilst the third is used for pumping purposes only. These shafts are described and their dimensions given. Flat cast-steel ropes are used for winding. The method of mining adopted is also described. At the Szekul Colliery

\* *Deutsche Kohlen-Zeitung*, vol. xvi. p. 638.

† *Berg- und Hüttenmännische Zeitung*, vol. iv. pp. 371-373.

four seams are mined of the respective thicknesses of  $2\frac{1}{2}$  feet,  $3\frac{1}{4}$  feet,  $4\frac{1}{2}$  feet, and  $6\frac{1}{2}$  feet. One shaft 1365 feet deep is in use, both winding and pumping being done in it. The seams dip towards the shaft, and at every 44 yards cross-cuts are put out from this to the seam. The coal is washed and subsequently coked at Reschitz. Each of these two collieries produces some 60,000 tons of coal a year.

**The Hungarian Brown Coal Mines.\***—The brown coal mines of the Rimamurány-Salgó-Tarján Steelworks Company, Hungary, are situated in Neograd and Borsod Counties. The Salgó mine, in the Medves plateau, is in the Neogene section of the Tertiary formation. Only one seam exists here thick enough to be mined to advantage. It varies from one to three yards in thickness. The seam is divided into three benches by narrow partings. The coal is black and dull in lustre. It appears to be rendered very impure by thin partings of shale. Its average calorific value is 3700 calories. The Salgó mine in 1895 produced 99,700 tons, and gives employment to 210 workpeople. At the Bánazállás Colliery, near Várkóny, two seams are mined. As in the case of the mine just mentioned, the coal has hitherto been won by adits only. In 1895 the production of this mine amounted to 108,800 tons. A shaft has now been sunk, however. A Capell fan is used, delivering 56,500 cubic feet of air per minute. The Járdánháza mine is also described. This mine produced in 1895, 66,300 tons of brown coal.

**The Fünfkirchen Collieries, Hungary.**—This coalfield is described at some length.† The following table shows the character of the coal:—

District.	Shaft.	Percentage Composition.					Calories C
		C.	H.	O.	N.	H <sub>2</sub> O.	
Fünfkirchen . . . .	Andreas	78·48	3·67	4·60	1·19	1·11	7,302
Do. . . . .	Do.	81·10	3·85	4·60	1·28	0·92	7,568
Do. . . . .	Schroll	77·32	3·93	5·08	1·34	0·95	7,288
Do. . . . .	Zwang	78·44	3·94	6·26	1·34	1·38	7,334
Szabolcs . . . . .	Franz-Josef	82·30	4·22	4·42	1·42	1·29	7,752
Do. . . . .	Do.	77·65	3·96	4·97	1·45	1·47	7,282
Do. . . . .	Do.	81·43	4·19	5·11	1·39	1·19	7,645
Do. . . . .	Do.	78·59	4·01	4·52	1·41	1·38	7,388
Vassas . . . . .	No. III.	77·75	4·11	6·40	1·39	1·47	7,303
Do. . . . .	Thommen.	75·81	4·22	7·44	1·24	1·61	7,130
Do. . . . .	Do.	74·85	4·06	5·78	1·23	1·27	7,052

\* *Berg- und Hüttenmännische Zeitung*, vol. lv. p. 313.

† *Ibid.*, pp. 421-424 and 429-431.

The average calorific value of the coal thus amounts to 7367 calorics. As far as the ash of these coals are concerned, they are of average character, the percentage varying from 6 to 25. Nearly the whole of the coal found in this district cokes well. Before being coked the coal is washed, and the coke then made contains from 10 to 14 per cent. of ash. The yield of coke is about 75 per cent. As yet the by-products are not collected. The Fünkirchen coal has the specific gravity of 1·3 to 1·6, a resinous lustre, and a velvet-black colour. The dust coal assumes a somewhat grey colour in time. In practice one kilogramme of the coal evaporates 5·5 to 6·5 litres of water, while the briquettes made from it evaporate 6·5 to 7·5 litres. At present sixty coke-ovens are in operation. These are on the François and Gobiet system, and details are given relating to their results in operation. The geological character of the field is described, and the methods of mining in use are referred to, together with other details. In 1895 the output of this field was the most important in Hungary, and amounted to 583,500 tons. In the period 1853-95, the total quantity of coal raised in this coalfield amounted to 12,385,400 tons.

**The Eibenthal Coalfield in South Hungary.**—The Lias of Eibenthal rests on gneiss, and is covered by porphyry.\* It contains coal-seams of considerable thickness. Coal has been mined at Eibenthal for about thirty years. The coal-seams occur in two groups, of which the eastern is far the more important. This contains the Wenzel bed, which is of great thickness, and possesses more the character of a massive deposit than a seam. The western group contains three seams, of 5, 26, and 52 feet thickness respectively. Bituminous slates form both the roof and floor of these seams, and on the floor side these carry blackband ironstones. Farther from the roof sandstones are met with.

The Wenzel seam is of very variable dip and thickness, the latter reaching to as much as 120 yards. The method of mining is described. Fire-damp is rarely observed in the mine, but Wolf benzene lamps are nevertheless employed. The quantity of coal in sight is estimated at 1,500,000 tons, but the quantity mined is very variable, and in recent years has not exceeded a maximum of 10,000 tons. An analysis of the coal showed it to contain—

Carbon.	Hydrogen.	Oxygen.	Nitrogen.	Sulphur.	Ash.	Hygroscopic Water.
80·77	3·59	2·58	0·75	0·73	11·66	0·65

\* *Berg- und Hüttenmännische Zeitung*, vol. lv. p. 305.

It also contained 0·002 per cent. of phosphorus. Eliminating the ash, moisture, &c., the coal substance is found to consist of—

Carbon.	Hydrogen.	Oxygen.	Nitrogen.
91·35	4·06	2·92	0·85

Calculated by the Dulong formula, this would have a calorific value of 8654 calories. The coal has the specific gravity 1·379.

**Peat in Hungary.**—The peat bogs of Hungary are divided into two sections, the upper and the lower. The former are unimportant. The lower bogs occur in the plains generally over a substratum of greyish-blue porous clay, and more rarely over loosely agglomerated quartz sand. Nearly always their beds are of recent, or at least of Quaternary age. Their depth is small, being, as a rule, not more than 6 to 8 feet; and only one, the Marcazal bog, near Hegyes, attains a thickness of 16 feet. These bogs occur in old lake beds or at the bottoms of gently sloping valleys. Occasionally they are found in the depressions in undulating sandy country. Lacustrine bogs, as a rule, are the most important in respect of the area covered, and included with them is the one in the county of Pest, which occupies what is apparently an old bed of the Danube, extending from the north of Pusztá-Gubacs to St. Ivan alongside the present course of the stream. At the present time, peat diggings are restricted to a very few localities, and the production is extremely small.\*

**Coal in Poland.**—A seam of coal has been discovered on the Krasnowice estate, Poland. The seam is about 15 feet in thickness, but it is not of such good quality as the Dombrova coal, and is overlain by quicksand.†

**The Coal Deposits of South Russia.**‡—In this district there are numerous seams of coal, though they are usually of no great thickness. The total quantity of fuel raised annually is some 4 million tons, larger, that is, than the out-turn of coal from any other district in Russia. The coal is good and cokes well. It threatens to replace coal from the United Kingdom in the coast districts, as the Government gives it

\* "Catalogue Général de l'Exposition National du Millénaire, Buda-Pest," 1896, Group viii. A.

† *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xliv. p. 634.

‡ *Stahl und Eisen*, vol. xvi. p. 863.

exceptionally low transport charges. Average analyses of the coal and coke are as follows:—

	Carbon.	Volatile Matter.	Hydrogen.	Sulphur.	Ash.	Calories.
	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	
Coal— Washed . . .	79·0	17·0	4·3	1·2	6·0	7,450
Unwashed . . .	71·0	19·0	3·6	1·2	12·8	7,330
Coke . . .	92·0	...	0·2	1·3	6·2	7,690

The ash contains:—

Sample.	SiO <sub>2</sub> .	Al <sub>2</sub> O <sub>3</sub> .	CaO+MgO.	Fe.	S.	P.
	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.
I. . . . .	55·1	29·8	8·9	9·8	0·88	0·28
II. . . . .	54·1	23·6	8·1	8·1	0·96	0·22

About 15 per cent. of the total quantity of the coal mined consists of anthracite.

**Coal Deposits of the Kirghiz Steppes.**—R. Helmhacker \* observes that in the Turgai government are two brown coalfields. One of these contains a seam divided by a parting into two benches, the one about a yard and the other a foot in thickness. In the other field there is a seam over 6 feet thick, and containing from 4 to 7 per cent. of ash. In the Asmolinsk government is the Kargandinsk Colliery. There are here two seams, the one 2 yards and the other 4½ yards thick, which yield a semi-caking coal containing 8 to 12 per cent. of ash. Other coal deposits exist in the Pavlodarsk district of the Semipalatinsk government, and several collieries are named, now mostly closed down, the seams of coal varying in thickness from 1 foot to about 5 feet, apparently mostly non-caking in character. Near the Alka-Sor Lake are two seams of anthracite approximately 4 and 12 yards in thickness respectively, the coal containing 12 per cent. of ash. Another colliery is mentioned which produced a caking coal, and yet another which possesses five seams of anthracite. Other deposits are also mentioned.

In the Eastern Kirghiz Steppes, in the Sergiopol district, some coal-seams have been met with up to over 2 yards in thickness. Some of

\* *Berg- und Hüttenmännische Zeitung*, vol. lv. pp. 171-172.

these yield a very serviceable coal, but that obtained from others of the seams crumbles when exposed to the air.

About ten or fifteen years ago the production of coal in the Kirghiz Steppes varied from 17,000 to 27,250 tons, but it subsequently fell to only 150 tons, but in 1891 it had again risen to from 1400 to 1500 tons, and will probably increase, aided by the new Siberian railway.

**The Mineral Deposits of Turkestan.**—Russian Central Asia is extremely rich in ore deposits.\* At present there are mined there, in addition to other minerals, iron ore, coal, naphtha, ozokerite, and *Rit*—an earth saturated with naphtha. Of coal, some 600,000 poods (say 10,000 tons) are mined annually. In the Syr-Darja district coal-seams are mined on the Kara-Tau range. In the year 1891 the statistics relating to coal-mining in the whole of Turkestan showed:—

District.	Mines.	Workpeople.	Coal Raised. Poods.
Syr-Darja . . . . .	2	23	1,800
Samarkand . . . . .	8	102	389,350
Fergan . . . . .	4	25	102,700
Totals . . . . .	14	150	493,850

In 1894 the quantity won in the Samarkand district had increased to 526,000 poods. A deposit of brown coal exists in the Mangischlak district. An assay of the Turkestan coal showed—

Fixed Carbon. 56·3 to 56·8	Volatile Matter. 33 to 40	Ash. 2 to 10
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Ozokerite is found on the island of Tscheleken and in the Balkan mountains. Formerly the output amounted to several thousands poods a year, but now, owing to labour difficulties, this output has much diminished. So far, only the surface beds have been worked. Two kinds of ozokerite are distinguished—one dark green in colour, containing 80 per cent. of paraffin, and a dark brown variety containing 60 per cent. It is found in narrow seams and stringers.

Naphtha occurs in several places, but it is not yet won in a regular manner. The best known deposits are those on the island of Tscheleken. Naphtha lakes occur here. The oil is transported to Persia. In 1893

\* *Berg- und Hüttenmännische Zeitung*, vol. lvi. pp. 57-58.

the Nobel Company obtained from here 117,500 poods of naphtha. Oil wells exist, too, on the Nefte-Dag mountain, and in the Fergan district 4590 poods of oil were obtained in the year 1891. In Transcaspia, in the latter year, 180,000 poods were obtained.

The so-called Rir is mined to the extent of about 2000 to 3000 poods a year on Tscheleken. It has also been met with in the Balkans. Iron ores are found in Transcaspia, in the Balkans, and in the Kara-Tau mountains in the Syr-Darja district. Accounts are also given of the occurrence of the other useful minerals in Turkestan. These include copper, lead, salt, sulphur, &c.

**The St. Makar Colliery, East Siberia.**—Four seams are mined here, varying in thickness from about half a yard to four feet. The coal in each seam is of a caking variety. As mined, this coal contains from 20 to 30 per cent. of ash, and has a pulverulent appearance. The coal is submitted to mechanical preparation, and the daily output is now 50 to 60 tons a day; but it is intended to increase this to 250 to 300 tons.\*

**Coal in South Africa.**—W. Gibson † gives a general sketch of the geology of Africa in relation to its mineral wealth. A number of sections and a geological map, compiled from various authorities, are given. The occurrence of coal in the Karoo beds in South Africa is mentioned, and this formation may also contain coal in Central and Northern Africa. A table showing the correlations of strata in South Africa, according to various authorities, is given; and a second appendix, covering three pages, gives a bibliography of the more important literature relating to African geology.

According to W. B. Worsfold,‡ iron is not worked anywhere in South Africa, although large deposits have been found. The coal deposits cover about 56,000 square miles, and the more important collieries are briefly mentioned, but the productions given are not more recent than 1892.

T. B. Shipley § describes the Heidelberg coalfield, a coalfield which has been generally overlooked by mining engineers who have recently described the Transvaal coalfields. The main seam is 22 feet thick

\* *Berg- und Hüttenmännische Zeitung*, vol. lv. p. 297.

† *Transactions of the Federated Institution of Mining Engineers*, vol. xii. pp. 303-326, with map.

‡ "South Africa," by W. Basil Worsfold : Methuen & Co., 1895, pp. 152-154.

§ *Colliery Guardian*, vol. lxxii. p. 1013.

clear of partings, and throughout is very even in quality. An average of several analyses gave the following results :—

	Per Cent.
Coke . . . . .	70·00
Ash . . . . .	10·30
Volatile matter . . . . .	22·57
Sulphur . . . . .	1·11
Moisture . . . . .	9·02

Percy Johns \* describes the Indwee coalfields. At Indwee the seam of coal now being mined outcrops along the range of hills overlooking the township. The seam is as follows :—

Roof . . . . .	Sandstone.
Coal . . . . .	6 inches.
Shale . . . . .	6 inches.
Coal . . . . .	6 inches.
Shale . . . . .	1 foot 2 inches.
Coal . . . . .	2 feet 2 inches.
Shale . . . . .	6 inches.
Coal . . . . .	10 inches.
Floor . . . . .	Sandstone.

Thus giving 4 feet coal out of 6 feet 2 inches seam. The workings are conducted by means of adits direct upon the coal, and are in some 600 yards, and the mine opens out well.

W. F. Brown † gives a succinct sketch of the Transvaal coalfield, mentioning the physical and geological features, the seams in the various districts, the quality of the coal, the systems of working, labour, railways, and markets. Sections of the seams and overlying strata, with a map, are appended.

According to Kuntz,‡ a seam of coal 70 feet in thickness has been found in the immediate neighbourhood of the goldfields in the Transvaal. The coal is, however, of poor quality, though it is quite good enough for use at the mines. In addition to this seam, and another deposit on the Vaal River, which largely supplies the coal used on the railway, even far down into the Cape Colony, enormous deposits of coal also occur in the Middelburg and Ermalo districts between Pretoria and Delagoa Bay, and the vicinity of a good port causes these latter to have a promising future. German capital is in part engaged in the opening up of these latter fields. In good positions all along the Delagoa Bay line of railway new coal workings are being constantly opened out. The coal exists in enormous quantity, but its quality is as yet somewhat uncertain. The best analyses have so far been shown by a coal found

\* *Diamond Fields Advertiser*, January 29, 1897.

† *Proceedings of the South Wales Institute of Engineers*, vol. xx. pp. 134-155.

‡ *Oesterreichische Zeitschrift für Berg- und Hüttewesen*, vol. xliv. pp. 55-56.

at some distance from the railway line. It contained 5·4 per cent. of ash. In the Ermalo district the coal is stated to be nearly of the same value as Cardiff coal, but neither of these deposits can be worked until they possess greater transport facilities. A branch line is projected. Coal found on the Elephant River, in the Middelburg district, is said to be of very good quality, and considerably better than that now put on the Johannesburg market. It is thought that the Transvaal Government might take in hand the opening up of these deposits. Considerable iron ore deposits are also found in the Middelburg district.

**Coal in Ontario.**—A. M'Charles \* discusses the supposed coal found 17 miles west of Sudbury, and pronounces it to be anthraxolite, and not true anthracite. He found the outcrop on the face of a slaty ridge, not in a bed, but in an irregular vein cutting across the rock formation almost at a right angle. An assay quoted from Professor Coleman's report shows : †—

Moisture.	Volatile Matter.	Fixed Carbon.	Sulphur.	Ash.	Total.
2·67	4·78	55·85	1·06	36·50	100·86

None of the assays show less than 20 per cent. of ash.

**Coal in New South Wales.**—E. F. Pittman ‡ gives some notes on the Ashford coalfield, in the county of Arrawatta, New South Wales. This field is the most northerly extension of the coal-bearing rocks of Permo-Carboniferous age in the country. It consists of a long narrow belt of conglomerates, shales, ironstone, and sandstone, with a seam of coal about 27 feet thick, divided by a number of partings. The measures dip W. 30° N. at an angle of about 40°. Granite bounding the area on the north appears to be intrusive, as it has altered the coal in parts, and the deposit is unconformable with what appear to be the Carboniferous (Gympie) claystones. Assays of the coal from various points show as follows :—

Hygroscopic moisture . . .	0·65	0·55	0·75	0·90
Volatile hydrocarbons . . .	22·15	24·65	23·25	21·55
Fixed carbon . . .	71·65	67·80	68·90	67·50
Ash . . .	5·55	7·00	7·10	10·05
Sulphur . . .	0·480	0·357	0·357	0·453
Specific gravity . . .	1·328	1·342	1·349	1·374
Water evaporated, lbs. . .	13·53	14·08	13·86	13·86

A map and sections of the district are given.

\* *Engineering and Mining Journal*, vol. lxii. p. 512.

† Report on Anthracite Carbon or Anthraxolite, Bulletin No. 2 of the Bureau of Mines, Toronto.

‡ *Records of the Geological Society of New South Wales*, vol. v. pp. 26-31.

**Coal in West Australia.**—H. P. Woodward,\* in a report on the Carboniferous area of the Irwin River basin, states that the Carboniferous area spreads out from Mingenew in an easterly direction, covering an area of about 200 square miles, its greatest length from north to south, from Badgeroo Pool upon the north branch to Mount Scratch, being about 30 miles, whilst its greatest width, from Mingenew to Narandagry, upon the Lockier River, is about 17 miles.

Assays of the coal gave the following results :—

Water . . . . .	17.04	12.4	15.63
Volatile matter . . . . .	28.61	32.2	23.06
Fixed carbon . . . . .	41.29	43.5	39.32
Ash . . . . .	13.06	11.9	21.99
	<hr/>	<hr/>	<hr/>
	100.00	100.0	100.00
Sulphur . . . . .	0.83	trace	

The large amount of ash may, in part, be due to extraneous earthy matter. The coal cannot be utilised for gas-making, as it does not cake, and the coke formed, being in powder, is valueless ; but the coal can be used for steam-boilers and household purposes, and for those metallurgical operations in which a particularly high temperature is not required. All these samples, it must be remembered, are of highly-weathered coal, and were taken from near the cliff face.

**Coal in California.**—The working of coal in California is still in a backward state, the largest concern employing about 30 men, according to the last State report,† which mentions the various mines and occurrences.

It is stated ‡ that the output in 1896 was 52,529 tons, as compared with 80,115 tons in the previous year. The imports have also fallen off, being 1,516,319 and 1,703,808 tons respectively for these two years.

**Coal in Indiana.**—What is known as the block coal district of Indiana covers about 350 square miles, but the deposits are local and of varying extent. The coal does not cake ; and an average assay of ten samples shows :—

Fixed Carbon.	Ash.	Volatile Matter.	Water.	Total.
56.83	1.66	36.50	5.0	99.99

Its specific gravity is 1.234, and calorific value 7983. There are three seams. The top or Rider seam ranges from a few inches to 5

\* Report of the Department of Mines, West Australia.

† Thirteenth Annual Report of the Californian State Mining Bureau, 1896, pp. 51-56.

‡ *Engineering and Mining Journal*, vol. lxiii. p. 62.

feet, and is not much worked. The two other seams are found at an average depth of 25 and 85 feet, average 4 feet, and between  $2\frac{1}{2}$  and  $3\frac{1}{2}$  feet respectively. The coal is strongly divided by cleat in two directions, so that it is worked out in blocks.\*

**Coal in Iowa.**—According to S. W. Beyer,† the Lower Coal Measures of Boone County completely underlie the county. The Des Moines River has cut into this formation a channel averaging 100 feet in depth, and revealing a series of sandstones and shales with several veins of coal, which are interbedded in a most intricate manner. It is probable the Coal Measures may reach a thickness of nearly 300 feet at a certain point. Lithologically, the Coal Measures strata consist essentially of sandstone and shales, which contain several seams of coal of greater or less extent. The coal is entirely bituminous, and has upwards of 80 per cent. of oxidisable elements, chief among these being carbon. Boone County has long been one of the leading coal-producing countries in the State. For nearly half a century it has been known to exist in the region in quantities of economic importance, and has long been mined to supply local wants. In the Madrid district the seam averages about 26 inches in thickness, is of fair quality, has a good roof, and is readily mined by drifting into the bank. The author gives the following analyses:—

	Coal.			
	1. Angus Mine.	1A. Dalby Mine.	2. Boones- boro'.	3. Fraser.
Average.	Average.	Average.	Average.	Average.
Moisture . . . . .	8·62	2·04	12·37	14·77
Total combustible . . . . .	82·75	88·36	81·90	73·71
Ash . . . . .	8·64	8·12	5·87	11·48
Volatile combustible . . . . .	38·33	43·08	48·24	37·67
Fixed carbon . . . . .	44·41	45·29	43·72	36·05
Coke . . . . .	53·05	54·08	49·41	47·53
Sulphur . . . . .	2·59	4·33	...	2·76
Sulphate . . . . .	0·08	0·14	...	0·19

**Coal in Missouri.**—In a paper read before the Geological Society of America, David White concludes that the two approximate low coals, which occasionally rest on the eroded surface of the Mississippian series in Henry County, Missouri, are slightly younger than the Brookville, Clarion, or Mazon Creek horizons of the northern bituminous fields,

\* *Engineering and Mining Journal*, vol. lxiii. pp. 162-163.

† Annual Report of the Iowa Geological Survey, vol. v.

though they are perhaps not so young as the middle Kittanning coal. The plant remains lead the author to suppose that the Henry County coals are partially contemporaneous with the transition series between the Upper and the Middle Coal Measures of Great Britain and the third or upper zone of the Valenciennes series in the Franco-Belgian basin.

**Coalfields of Esmeralda County, Nevada.**—M. A. Knapp \* describes this coalfield and its interesting stratigraphical relations.

**Coal in Oregon.**—In an interesting account of a geological reconnaissance in North-Western Oregon, J. S. Diller gives, in the seventeenth Annual Report of the United States Geological Survey, a description of the coalfields of that region. The age of the coal is in some cases that of the Eocene formation. In other places the coal occurs in beds known to be older than some Miocene beds. At Coos Bay the age is somewhat uncertain, but the evidence points rather to Eocene than Miocene age.

**Coal in Utah.**—In the *Salt Lake Tribune* J. M. Goodwin describes the occurrence of coal in Utah. At Coalville coal has been mined for the past thirty years, some of the mines having been worked out years ago. The most productive mine at present is that worked by the Weber Coal Company. This mine is provided with modern appliances and employs sixty men, the average output per shift being 250 tons. Miners are paid 16d. per ton.

**Discovery of Coal in German East Africa.**—A. Merensky † reports that coal has been found in large quantity to the north-west of Nyassa, in 9° 32' 20" S. latitude and 33° 44' E. longitude. Samples of this coal have reached Berlin. The discovery was made at a point about twenty-five miles from the point where the Songwe River enters the Nyassa. The coal-seams are large, and they outcrop. No assay of the coal is given.

Hauhecorne, the President of the German Geological Society, communicated particulars from Bornhardt ‡ of the coal deposits discovered between the Nyassa and Tanganyika lakes. A seam about 16 feet in thickness was found, about eight miles north-east of the Nyassa, of coal containing 9 to 15 per cent. of ash, and having calorific power of 7000

\* *Mining and Scientific Press*, February 13, 1897.

† *Deutsche Kolonial-zeitung*, through *Stahl und Eisen*, vol. xvi. p. 935.

‡ *Engineering and Mining Journal*, vol. lxiii. p. 142.

and 6000 calories. The coal appears to be of the same age as the Transvaal coal.

**Coal in Borneo.**—Assays\* of coal from three mines in Borneo have recently been published:—

	Sadong.	Labuan.	Muara.
	Per Cent.	Per Cent.	Per Cent.
Volatile matter . . . . .	42·04	42·34	47·54
Fixed carbon . . . . .	56·27	54·97	50·79
Ash . . . . .	1·69	2·69	1·67

**Coal in Tonkin.**—F. Brard † describes the Hongay collieries, Tonkin, the two most important of which are the Nagotna and Hatou. At the former four seams, varying in thickness from 5 to 16 feet, are being actively worked; and at the latter there are two seams, one of which, from 30 to 40 yards thick, is worked opencast and also by headings. The characteristic feature of the Hongay coal is its low ash content, as the seams are free from shale bands, the shales of the various deposits occurring in distinct beds.

**The Nondoué Collieries, New Caledonia.**—These collieries had their origin in the discovery of some outcrops about fifteen miles from Noumea in 1890. Thirty coal-seams have been met with, varying between about 3 feet and 16 feet in thickness. The coal is of good quality. The seams are not seriously faulted anywhere.‡

**Formation of Coal.**—W. S. Gresley § argues that the brilliant black laminæ in coal, and similar materials to those that form these laminæ which are found in earthy coals, shales, and clays, point to the former existence of an aquatic plant having the general shape of the modern *Platycerium alcicorne*, which grew *in situ*. He believes that much coal was formed by this aquatic "coal-plant," which grew amongst the mechanical sediments and the debris of the terrestrial vegetation that accumulated on the floors of sheets of water.

\* *Indian Engineering, through the Engineering and Mining Journal*, vol. lxii. p. 436.

† *Bulletin de la Société des Ingénieurs Civils*, vol. i. pp. 81-112.

‡ *Berg- und Hüttenmännische Zeitung*, vol. lv. p. 18.

§ Paper read before the Geological Society, February 24, 1897.

### III.—*CHARCOAL.*

**Wood Distillation in Russia.\***—Of late years great advances in applied science have been made in Russia. The enormous pine-forests have, however, been more or less neglected, because it was assumed that the Russian fir did not yield turpentine and rosin equal in quality or quantity to the American and French produce. State experiments have lately shown that the Russian turpentine, when collected by the French method, is chemically identical with the French, but is dextro-rotatory to the same degree as the other is laevo-rotatory. The industries connected with the dry distillation of wood are as yet in their infancy, but in a few years Russia may be in a position to export all the valuable products of this operation.

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### IV.—*COKE.*

**Improvements in the Manufacture of Coke.**—F. Simmersbach † traces the progress of the coke industry in the Dortmund district in the past decade. In 1894 the production of coke in Germany reached 8,941,391 tons, and of this quantity the Dortmund district produced 71·2 per cent., Silesia 17·2 per cent., the Saar and Aix-la-Chapelle districts 10 per cent., the Oberkirchen district 0·3 per cent., and the kingdom of Saxony 0·9. The value of the coke made was upwards of four millions sterling. The first attempts to produce coke in Germany date back for over a century, and were made in the Witten district. Attempts to use coke in the blast-furnace are stated to have been made at the Gutehoffnungshütte near Sterkrade as far back as 1790, but these, as also the use of coke in the cupolas, led to no satisfactory results. It was only towards the end of the forties that the exclusive use of coke in a blast-furnace came into practice. The introduction of railways gave a further impulse to the manufacture of coke, and in the early days it was stated that 90 per cent. of the coke made in Germany was used on the railways. This coke was made in heaps, Schaumburg ovens, and in part in the Welsh closed oven. Until 1850 the coal was coked as mined, and its preliminary treatment received no consideration until that year. In 1850 the out-turn of coke in the Dortmund district was

\* *Chemist and Druggist*, 1897, p. 56; *Imperial Institute Journal*, vol. iii. p. 122.

† *Zeitschrift für das Berg-, Hütten- und Salinenwesen im preussischen Staate*, vol. xliv. pp. 402–418.

but 73,112 tons. By 1870 it had risen to 341,033 tons, and in 1880 the production reached 2,280,000 tons, increasing to over four millions in 1890, and to 5,398,612 tons in 1894, or double the production of 1884. The imports and exports of coke from the German Empire have been as follows in the years mentioned :—

Year.	Imports.		Exports.
	Metric Tons.	Metric Tons.	
1885 . . . . .	151,124	633,897	
1890 . . . . .	351,258	1,074,755	
1894 . . . . .	404,179	2,261,924	

The imports reached a maximum of 465,726 tons in 1892, since when they have steadily diminished. The value of the imports of coke has rather more than trebled since 1885, whilst the value of the exports has increased from £395,000 to £1,775,000.

In the manufacture of the 5,398,612 tons of coke produced in 1894, 61 works took part. The minimum number of coke-ovens possessed by any one works was 10, and the maximum number 1121. The statistics quoted do not take into consideration the coke consumed at the producing works themselves. In 1885–87 the ton of coke sold for 7s. to 8s., but in 1893–94 the price was 11s. In the year 1890 it rose to the high price of 26s.

With regard to our knowledge of the chemistry of the coking process, the author considers that a great deal still remains to be learnt. For instance, it is still uncertain why certain kinds of coal are caking coals and others not. The assumption that some relation existed between the percentage composition of caking coals and the ready fusibility peculiar to these was soon abandoned, for there are coals high in hydrogen and oxygen on the one hand, and low in these elements on the other which are non-caking, while intermediary coals possess that property. Again, there are coals of identically the same percentage composition which are entirely different in their caking properties. Various views exist to which the author draws attention, and the author considers that Science would render great assistance to Trade if this question could have further light thrown upon it, especially in connection with the coking of non-caking coals. Practical experience has, indeed, in one sense progressed more rapidly in this direction than has a scientific knowledge of the subject, for it has been shown that the non-caking properties of certain coals can in part be met by an increase in the temperature employed during the coking process.

The question whether in some coals a certain percentage of water is useful in coking is still an open one. The chief advantage of a damp coal is held to be that it lies closer together in the coke-oven, and consequently yields a denser coke, and that it tends to counteract any blowing-out of the coke by a too rapid evolution of gas, which would happen in a very gassy coal. Doubtless pressure would have the same effect in many cases, or a heating of the oven walls during the earlier stages of the coking process, and only in such cases, perhaps, where such methods are not applicable, is the wet condition of the coal justifiable. The disadvantages connected with the presence of moisture are numerous. Heat is required to drive off this water, and this heat is lost to the coking process proper. How much it may amount to is seen when it is remembered that in a battery of 60 ovens, 1590 cubic feet of water may have to be evaporated daily, if the percentage of moisture in the coal reaches 15. Then, again, the heating value of the gases resulting from the coking process is diminished. The author does not consider the contention a valid one that moisture is necessary in the coal that is to be coked in a battery provided with plant for the collection of the by-products, to prevent particles of coal being drawn forward into the pipe-ways, because the pressure ought to be so regulated as to render this impossible, a manometer being employed.

Much has been done in recent years with regard to the examination of the products resulting from the coking process. The structural conditions of the coke, its specific gravity, its differing behaviour in the blast-furnace, and the degree in which it is acted upon by carbon dioxide and other gases, have all been the subject of investigations which have led to many valuable conclusions. This is less true, however, as regards the gaseous products and their formation, although a true knowledge of this would be of the greatest value in connection with the collection of the by-products. The conditions under which the gases result which yield the tar, ammonia, and benzene are still inadequately investigated, and at present one has to be satisfied with hypotheses. Practice has at least shown that the use of a high temperature in coking, if it leads to the formation of less tar, at least produces a tar of a higher commercial value, and that it also leads to the collection of a higher percentage of ammonia. In batteries of ovens which are not provided with condensing plants, the gaseous products from the coking process are now found to be of great value for steam-raising purposes; but this method of utilising them is by no means old, and only began about the year 1850. In the Ruhr district there are still a number of ovens which

are neither provided with condensing plants, nor with any methods for utilising the heat obtainable from their waste products. It was formerly considered that for every pound of coal charged into the coke-oven a pound of water could be evaporated, but this quantity can now by proper working be largely increased. It was at first a matter of dispute whether it was more profitable to collect the by-products or to burn them for steam-raising purposes; but this cannot now be held to be doubtful, for even with the collection of the by-products a much higher steam-raising power can be made available than existed with the older methods of coking; for manufacturers have learnt to obtain greater and greater quantities of available gas during the coking process by diminishing that necessary for the heating of the ovens. Thus, at the Phoenix Works, for every pound of coal charged into the ovens, the gas excess and waste heat generally enables 1.26 lb. of water to be evaporated, and still better results have been obtained at other works.

With regard to the methods of construction of the coking-ovens themselves, a great deal has been done in recent years. Regenerators, vertical channels, the construction of the dividing walls between two adjacent ovens, and many other points have received attention. The number of the different types of coking-ovens in use has undergone diminution. Some, including the Smet and the Appolt ovens, have entirely disappeared. The number of "round" ovens, too, has diminished in the Dortmund district from 762 in 1885 to but 142 in 1895. In the latter year 54 per cent. of the total quantity of coke made in that district was capable of being produced in existing plants provided with condensing plants for the recovery of the by-products. The Otto-Hoffmann type is that chiefly in use. The length of an oven of this kind is 32 feet 9.7 inches. In height it is 70.8 inches, and in average width 20.9 inches. Its charge is 6.550 metric tons—dry weight—of coal, and the coking period for fairly dry coal is thirty hours. Per day and per oven about 4 tons of coke results. Some changes have recently been made in the construction of this oven, to which the author refers, and a battery of ovens of this modified type has been erected near Steele. The coal coked contains about 16 per cent. of volatile products. The oven-chamber is 16.14 inches wide at the ejector end, increasing to 19.29 inches at the other. The coking period is from twenty-four to twenty-six hours. In conclusion, the author gives a list of the coke-oven plants provided with condensing apparatus for the collection of the by-products which are in use in the Dortmund district. These numbered 30, with 1864 ovens in 1895, as compared with 15 possessing 862 ovens in the pre-

vious year, and 10 with 536 ovens in 1890. Statistics are also quoted showing the variations in the price of the tar, ammonium sulphate, and benzene produced for each of the years 1885–95. The ammonium sulphate shows little average diminution in price, but the other products have diminished to one-half and one-third of their original market value.

**Coke-Ovens.**—Further illustrations have appeared\* of the Otto-Hoffmann oven, of which the details in the later forms have been modified in several respects. In one form the regenerative chambers are set in front instead of under each end of the ovens, under which air can circulate freely. The chambers have also been reduced in size and the conduits simplified. The substructure is also arranged differently.

Other illustrations have been published† of the condensation and washing plant erected at Constantine the Great Colliery, near Bochum, in Westphalia, for a battery of sixty Otto-Hoffmann ovens. Some details of the production of Semet-Solvay ovens are also given.

**Coke-Oven Gases.**—The improvements which have been made in connection with the utilisation of coke-oven gases are dealt with in *Stahl und Eisen*.‡ The collection of cyanogen from such gases is first considered. The occurrence of cyanogen in the blast-furnace has long been known, potassium cyanide being frequently observed. This occurrence is interesting in that it shows that the nitrogen of the air must have taken part in the formation of the cyanide. Bunsen was the first to prove this experimentally. A very high temperature is necessary for this reaction to take place. It may be shown experimentally that when ammonia is passed over red-hot coal contained in a porcelain tube, cyanogen is formed. The same result must ensue in the coke-oven, influenced, it is true, by the degree of temperature existing there, the admixture with other gases, and the rate at which these gases are passed over or through the coal. The occurrence of cyanogen in the coke-oven gases is undoubtedly mainly due to the decomposition of ammonia formed earlier in the process. It is evident that if the ammonia has been largely converted into cyanogen, much of it cannot be present in the coke-oven gases, and that similarly there cannot be in these at the same time both much ammonia and much cyanogen. Undoubtedly, too, the use of a high temperature favours the formation of the ammonia, but a high temperature, again, may lead to a considerable decomposition

\* *The Engineer*, vol. lxxxiii. pp. 207–209.

† *Ibid.*, pp. 231–232.

‡ Vol. xvii. pp. 90–94; *Journal für Gasbeleuchtung*, 1897, No. 2.

of the ammonia formed. The Foulis process is then referred to and described. There is an English patent for this dated 1892.

The next point dealt with is the utilisation of the coke-oven gases for illuminating purposes. Without purifying and without the addition of benzene the illuminating power is about one-half that of illuminating gas, due mainly to the atmospheric air with which the coke-oven gas is mixed. The gas can be easily carburised and so have its illuminating power increased. At a Belgian coke-oven plant, the gas, after purification and carburisation, has an illuminating power estimated at about 15 or 16 candle-power. It is used partly as an illuminant at the works, and partly finds use at a neighbouring steelworks. The following are some comparative analyses :—

	Coke-Oven Gas.			London Illuminating Gas.	Birmingham Illuminating Gas.
	I.	II.	III.		
H <sub>2</sub> S . . .	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.
CO <sub>2</sub> . . .	3·8	3·3	...	...	...
O . . .	...	...	...	0·1	...
C <sub>n</sub> H <sub>2n</sub> . . .	4·3	3·7	3·7	4·7	4·9
CO . . .	10·1	9·9	9·8	7·5	6·8
CH <sub>4</sub> . . .	29·6	22·9	29·4	34·2	37·5
H . . .	52·2	45·9	57·1	49·2	46·2
N (difference) . . .	...	13·5	...	4·3	4·6

Nos. I. and II. were the unpurified gas. In the case of II. a great deal of air had been drawn in.

The use of raw benzole for carburisation purposes generally is then dealt with. It should be as free as possible from totuol and xylol. At the present time only about 5 per cent. of the illuminating gas made in Germany is improved in this way.

**The Manufacture of Coke at Bilbao.**—B. de Heredia\* describes the installation of Simon-Carves coke-ovens at the works of the Vizcaya Company, giving full details of the plant.

**Coke-Oven By-Products.**—W. M. Brewer,† in discussing the Southern coke industry in the United States, refers to the saving of by-products, and shows how the price of these materials, the cost of the plant, and the quality of the coke are all factors to be considered. The

\* *Revista tecnologico-industrial*, vol. xx. No. 1; *Colliery Guardian*, vol. lxxiii. p. 491.

† *Dixie*, through the *Iron Trade Review*, vol. xxix. No. 53, p. 11.

plants erected already in America for the saving of these products are being carefully watched.

The utilisation of coke-oven gases forms the subject of a communication by G. Hausdorff,\* who observes that, up to the present time, the only by-products recovered from these gases have been tar, ammonia, and benzol. The gases contain, however, other gaseous substances which may be extracted with advantage. These substances also contain carburetted hydrogen. Hitherto benzol has been the only substance recovered; but lately the Fritzsche method for the separation and utilisation of ethylene has been proposed, in which this gas may be combined with sulphuric acid to form sulphate of ethylene so as to produce ether and alcohol. Only in 1876 was it discovered that the combination of ethylene with sulphuric acid, which takes place very slowly at ordinary temperatures, can be effected from thirty to fifty times more rapidly at a higher temperature. In the Fritzsche method the coke-oven gas is treated (after the tar, ammonia, benzol, and sulphuric acid are extracted) first with cold strong or warm diluted sulphuric acid, both for drying the gas and eliminating the carburetted hydrogen of condensation; and it is this gaseous carburetted hydrogen which, in contact with sulphuric acid, is transformed into liquid but not volatile substances, when the gas, thus purified, is treated with hot concentrated sulphuric acid, by which the ethylene is separated and sulphate of ethylene produced.

#### V.—LIQUID FUEL.

**The Origin of Petroleum.**—C. Ochsenius † observes that it is now settled that petroleum has its origin in organic remains, and briefly refers to the beliefs formerly held as to this origin and the gradually acquired proof. He refers also to recent work in this connection, and observes that the formation of petroleum from fat can be considered as having taken place in two stages, the first of which was copied experimentally by Engler, while the secondary conversion followed very slowly, and was, as a rule, not quite complete. He deals in some detail with his subject.

**Uses of Petroleum.**—J. S. Thurman ‡ discusses the advantages of the use of crude petroleum as fuel for firing steam-boilers, heating fur-

\* *Glückauf*, vol. xxxii. pp. 951-953.

† *Berg- und Hüttenmännische Zeitung*, vol. lv. pp. 201-203.

‡ *The Age of Steel*, vol. lxxxi. No. 12, pp. 15-16.

naces, and other purposes. The advantages are ease of application and control, economy of labour, and efficiency. Three barrels of 42 gallons each are given as the equivalent of a ton of coal.

W. L. Watts \* gives some particulars of the use of oil as fuel in California, where it is largely used on the locomotives of the Southern Californian Railroad, with the result that 4 barrels of oil are found to be equivalent to 2200 lbs. of Nanaimo coal, and a considerable pecuniary saving is effected. At the Los Angeles Steelworks,  $2\frac{1}{2}$  to 3 barrels of oil are equivalent to 2000 lbs. of bituminous coal for heating and steam-raising. Other works also use oil in place of coal with various forms of atomising burners. Calorific tests showed a range of 9999 to 10,381 kilocalories for various samples, as compared with 6684 for Nanaimo coal.

At a meeting of the North-East Coast Institution of Engineers and Shipbuilders, held on the 10th February, R. Wallis read a paper on "Liquid Fuel," with special reference to its use on board ship. He explained that the principal source of fuel oil was Russian petroleum residuum or "astatki;" this was the oil remaining in the distillery apparatus after the lighter naphthas and paraffins had been distilled over. Russian crude petroleum yielded a very much smaller percentage of burning oils than American crude oil, but fuel oil in Russia, where astatki was used for this purpose, was cheaper than in America, where crude oil was used. In addition to the petroleum oils the following oils had also been used as fuels:—Shale oil, blast-furnace oil, creosote, green and other tar oils. Comparing the value of coal and oil as fuel, it would be found to vary considerably according to the quality of the fuel and the circumstances under which each were burnt, oil doing from one and a half to two and a half times the work of an equal weight of coal; taking the average conditions, the results of extended experience with astatki and crude petroleum showed that these oils will be found to do twice the work of coal.

Wagner † discusses historically the uses to which petroleum was put in former times, and then deals with its origin and with the petroleum industry in various countries. He next passes to a consideration of its transport across the ocean, and describes the tank-steamers and others used in its transport.

Under the title of "Sketches in Crude Oil," J. J. McLaren has

\* Thirteenth Annual Report of the Californian State Mining Bureau, 1896, pp. 662-664.

† *Zeitschrift des Vereines deutscher Ingenieure*, vol. xli. p. 289.

published at Harrisburg, Pennsylvania, an entertaining account of the development of the petroleum industry of the United States. The rapidity of the development has been remarkable. In 1860 the petroleum exported from New York was 1300 gallons, valued at £170. In 1861 it was 12,700 gallons, and the price of refined oil was 2s. 6½d. per gallon. In 1894 the export was 908,281,968 gallons, and the price of refined oil was 2½d. per gallon. The book contains about 200 portraits, and anecdotes of the founders of this colossal industry.

A graphical chart has appeared \* showing a record of borings, of which the abscissæ are times and the ordinates depths, thus clearly showing the rates at which various portions of the work have progressed.

**Purification of Petroleum.**—The difficulty experienced in purifying petroleum by the aid of fuming sulphuric acid, owing to the formation of globules formed of an outer coat of pitch-like impurities and an inner nucleus of unwashed oil, has been overcome by an ingenious patent. Two streams, one of the oil and one of the acid, are made to impinge on each other at different velocities. A grinding action is thus produced which prevents the formation of globules and secures a much greater washing effect.†

**Production of Oil from Shale in France.**—This industry, F. Miron ‡ states, was commenced in 1830, at which date Laurent showed that when a bituminous shale is heated in a closed retort an oil is obtained which, on suitable treatment, yields combustible and lubricating oils, paraffin, ammonia, water, and tar. Numerous works were commenced in France, and subsequently in Scotland. The rivalry caused by the large imports of petroleum caused the industry in France to be on the point of collapse, and thus led the French Government in 1890 to put a premium on every hectolitre of the oil produced. Improvements taken from the Scottish factories were subsequently introduced into French practice.

At Autun, in the Permian formation, there is a deposit covering some 47,000 acres. Here nine beds of shale exist, seven of which are worked. In thickness they vary from about 2 to 2½ yards. At Buxières there are two deposits, also in the Permian, but only one is mined. At Autun in

\* *La Revue Technique*, February 10.

† *Journal of the Society of Chemical Industry*, vol. xvi. p. 38.

‡ *Revue Technique*, 1896, pp. 442, 512.

1890 156,000 tons, and at Buxières 51,000 tons of shale and 9000 tons of "boghead" were mined, the latter being used in enriching the gas. In the neighbourhood were eleven large and eight smaller oil distilleries. In the same year in Scotland eleven companies distilled two million tons of shale.

The oil-shale is found at a depth of from 50 to 100 yards or more. Boreholes are first put down to determine its limits, and then a main working shaft is sunk in a good position, such that haulage underground shall be as little as possible. The method of mining is described. Leather belts are used for the transport of the shale to the furnaces, this having been first broken small. Cast iron retorts of large size are used. The gases are brought back from the condensers, and are used in supporting the combustion, the hot distilled shale, which takes fire immediately on being discharged from the retort, being used for the same purpose. The distillation process lasts twenty-four hours. During the first four nothing but steam escapes, but subsequently it begins to get mixed with ammonia. From the fourth hour to the twelfth hour the percentage of steam in the gases diminishes, and finally ceases altogether, while the oil begins to show in larger and larger quantities. For a further eight hours only oil distils, gradually diminishing for the last four hours, when some steam, which again shows itself, becomes visible. The system of condensation used is described. When the distillation is effected at a high temperature, the specific gravity and quantity of the oil increases. If the shale was left too long in the open, the percentage of oil and of ammonia obtainable from it diminishes. By the introduction of steam, as in the Scotch process, the yield of oil is doubled, as has been shown by Chesneau. One cubic metre (35·3 cubic feet) of shale weighs from 1 to 1·2 ton, and yields, when distilled in the manner described by the author, from 9 to 15 gallons of raw oil, 11 to 13 gallons of ammoniacal water, and 883 to 1236 cubic feet of gas. A plant of fifty retorts requires about two hundred workpeople, about three-fourths of whom would be employed in the mine, twenty-five at the retorts, twenty-five in winding and separating, and about half-a-dozen smiths and carpenters.

The raw shale oil has a specific gravity of from 0·870 to 0·910. Its composition is but little known. It appears to consist of hydrocarbons of the series  $C_nH_{2n}$ ,  $C_nH_{2n+2}$ , and  $C_nH_{2n-6}$ , together with variable quantities of phenol derivatives. The raw oil contains also paraffin and sulphur compounds, which impart to it its disagreeable garlic flavour. The ammonia water contains ammonium carbonate and ammonium

sulphide. One ton of shale yields under the usual treatment about 1½ to 13 lbs. of these latter products.

**Oil in Roumania.**—According to E. Braun,\* several new wells have been drilled in Roumania. The return for capital expended in drilling wells is nothing like that obtained by the natives with dug wells, and this may be partly ascribed to the bad selection of sites. The inclined and wet sandy strata require that the wells should be started of large size—say 20 to 25 inches, but 10 or 12 inches diameter is often adopted, with the result that the tubing soon becomes so small that depth cannot be attained, or else the outrush of gas chokes the bore with sand. Dug wells are sunk where the oil-bearing strata crop out, and though the oil is not found in large quantities, yet it soon accumulates in larger quantities than in drilled wells. The cost of digging is extremely low.

C. Ochsenius† observes he has recently had information from Roumania bearing on the relationship existing between the beds of salt and the petroleum deposits, and it affords further evidence on a large scale of the truth of the laboratory experiments showing that concentrated salt solutions have played an important part in the formation of the oil. As far as is yet known, the salt-beds of Roumania begin near Ocna (Ocnele Mari), on the Aluta. They occur in the Tertiary (Miocene) formation. Farther to the east are the beds at Doftana; then come those of Slanicu (Targu), and finally that of Ocna, on the Trotus. All lie at about the same distance from the crests of the Carpathians, and they therefore represent a coast-line existing at the upheaval of this mountain range. The Carpathians continued to rise, and in doing so formed another coast-line from 18 to 25 miles distant from the one just mentioned, which was then entirely cut off from the sea, and this represents the position of the petroleum deposits of Targovist, Buzau (Buzen), and Bakau, on the Bistrizza. There must have existed there a rich flora and fauna, and the author holds that the residual concentrated salt solutions from the salt beds just referred to found their way to this coast-line, poisoned everything living in the water along this coast-line, and so gave rise to the present petroleum deposits. The author does not hold, however, with the belief that every salt bed must have a petroleum deposit in its vicinity. The author refers to the fact that in former days Russian military posts on the east

\* *American Manufacturer*, vol. lix. p. 914.

† *Berg- und Hüttenmännische Zeitung*, vol. lvi. pp. 27-28.

shore of the Caspian had to be abandoned because of the sudden destruction of all the fish that had previously been found in quantity along the coast there.

**The Petroleum Industry of Russia.**—E. Davidson \* observes that in connection with the Exhibition at Nijni-Novgorod, a Russian official publication was issued, which included an article on the Russian naphtha industry by Professor Lissenko. In this the author gives the following information. Throughout Russia, from the Island of Sagalian to the western borders of Poland, petroleum wells are found, but it is especially in the Apscheron peninsula, in the neighbourhood of Baku, that the industry has become concentrated. Thus in 1892 there were, in all in Russia 167 petroleum refineries, but of these 135 were at Baku. It is not merely the number of such refineries, however, which has to be considered, but also their size, and at Baku there are some which distil up to 45,000,000 poods, a quantity much larger than elsewhere. In the year 1893 general attention was directed to the oil-springs of the Terek district, but thus far a naphtha industry has not yet been commenced there, though some 20,000,000 poods of the raw products are obtained. This consists as to 18 per cent. of gasoline, 20 of kerosine, and 60 of naphtha residues. Within twenty years there were obtained in the Baku district more than three thousand million poods (1 pood = 36·1 lbs.) of oil, and still every year more and more new wells are giving excellent returns. Originally the distillation vessels in use at Baku were of small size, but now they usually average a capacity of 1000 poods each, though the 135 stills in use in 1891 had a total capacity of 616,454 cubic feet. Calculating the weight of a cubic foot of the raw oil at 1½ pood or 60 lbs., and assuming that the stills would not be more than two-thirds filled, it follows that the total working capacity of the stills at one time was as much as 600,000 poods of raw oil. At one works there was a still holding as much as 15,000 poods. The great improvement in the petroleum industry of Baku in the eighties was the introduction of the use of superheated steam in the distillation of the raw oil—a method which gave much more satisfactory results than the older method. The distillates, too, were much purer; for while formerly the quantity of sulphuric acid that had to be used in the purification was from 1·5 to 2 per cent. and that of caustic soda about 2 per cent., now 0·7 per cent. of sulphuric acid and 0·3 of alkali is all that is required. In the United States the raw oil is distilled without the use

\* *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xlv. pp. 31–36 and 51–55.

of steam, and frequently with a resulting decomposition. They obtain in this way 70 per cent. of illuminating oil. In Baku, on the other hand, particular care is devoted to preventing the decomposition of the raw naphtha, but only 36·5 per cent. of illuminating oil results. The increase in the exports of petroleum of late has drawn attention to this, and the author draws attention to two ways in which the difficulty can be met. He also refers to other improvements which have been made in the system of distillation in use. In Baku, 15 works now possess continuous apparatus, and their out-turn comprises 75 per cent. of the total production, the remaining 25 per cent. being spread over some hundred and twenty smaller firms. The chief difference between the refined Baku illuminating oil and that of the United States lies in its different specific gravity, that of the former being 0·820, while that of the latter is only about 0·800. This is due in part to the different chemical composition of the oil, and in part to the difference in the systems of distillation in use. It was found at Baku that, provided the distillate had not a specific gravity greater than 0·830, it burnt quite as readily in ordinary lamps as American petroleum. Illuminating oil of this specific gravity is now, therefore, made by mixing together the different fractional distillates of the specific gravities 0·790 to 0·860. Products with a higher or lower specific gravity than these are not used.

The residues resulting from the distillation are known as Masut. They contain many valuable constituents, and among others the lubricating oils. The demand for the latter is, however, very limited, and the residues are consequently but little used in the preparation of these oils, and are chiefly sold as fuel. For this purpose they must fulfil two conditions. They must not be too heavy—their specific gravity is usually 0·906 to 0·910—and they must not be of too fiery a character; that is to say, they must not give off inflammable vapours at low temperatures. With normal residues this temperature is 120°, but is usually lower, in consequence of the admixture of naphtha. The following table shows the exports of these residues and of purified and unpurified petroleum from Baku in the years mentioned:—

Year.	Petroleum.	Residue.
	Millions of Pds.	Millions of Pds.
1882 . . . . .	13·5	23·3
1885 . . . . .	28·0	60·5
1890 . . . . .	65·7	97·1
1894 . . . . .	69·6	193·5
1895 . . . . .	79·6	180·3

Since 1880 benzene and gasolene have been largely produced at Baku, and the demand for the former is a constantly increasing one. In 1882 the exports of this product from Baku amounted to only 7000 poods, while in 1894 it was 310,959 poods, and in 1895 300,599 poods. The solar illuminating oils are next dealt with. In 1895 their exports from Baku amounted to 1,145,004 poods. This export shows a steady diminution, though the export of the unrefined oil is increasing again. The specific gravity of these oils is from 0·870 to 0·890. Next to these follows an oil the best quality of which has the specific gravity of 0·890 to 0·900 ("spindle oil"), a flaming-point not below 150° C., and it does not solidify at -15° C. It is used for lubricating purposes, as, too, is the "machine" oil coming next. This has the specific gravity 0·905 to 0·910, a flaming-point not below 180°, and it again does not solidify at -15° C. Next comes a "cylinder" oil, having the density of 0·911 to 0·917, a flaming-point of 210°, and it does not solidify at -1° C. The first of these oils should at 50° C. flow through a narrow tube 5·1 times, the second or "machine" oil 7·5 times, and the third 15 times slower than water. Details are given as to the quantities exported of each of these oils. Next follow details showing the total exports of petroleum from Baku to different countries, and then it is pointed out how the progress of the petroleum industry at Baku has led to the establishment there of other industries on an important scale, especially of sulphuric acid and caustic soda. These are described. Various other statistical details relating to the petroleum industry at Baku are also given.

**Oil in Algeria.**—A. Evrard \* states that after three dry wells had been sunk at Ain Zeft, a fourth well, 1364 feet deep, encountered the oil-sand in June 1895, and yielded 4400 gallons daily, falling to 1540 gallons later. At Sidi-Brahim a heading 16 feet long struck a permanent oil spring yielding about 6 gallons of oil daily. Two wells have also been sunk, one to a depth of 748 feet, and it passed through traces of oil at five levels, and gas at a depth of 604 feet. The Sidi-Brahim oil, and that from the undeveloped sources at Taghria, are expected to yield 15 per cent. of burning oil, 28 per cent. of intermediate oil, 31 per cent. lubricating oil, and 23 per cent. of paraffin, vaseline, &c.

**Oil in Ontario.**—The petroleum area in Ontario is gradually widening. In Petrolia and Oil Springs districts there are upwards of 10,000 yielding wells, with an average of a third of a barrel daily. The Both-

\* *Génie Civil*, vol. xxix. pp. 235-237.

well field, abandoned in 1866, has resumed activity, with about forty producing wells, averaging five barrels daily. Natural gas is also obtained in the country.\*

**Oil-Shale in New South Wales.**—The shales worked in New South Wales are stated † to give 50 to 150 gallons of oil per ton, and to occur over 250 miles of country. About 120 feet above the shale there is a useless seam of coal which serves as a guide. The shale is found in small isolated seams all on the same horizon. Seams of 6 inches in thickness are too expensive to work. The best known deposits are those worked at Joadja Katoomba, Megalong Valley, and Hartley Vale, then crossing the Blue Mountains, Marangaroo and Capertee, and farther still north of Mudgee the Baragon and Reedy Creek deposits, and still farther on to Murrurendie. Between the Capertee and Wolgan rivers a deposit covering five square miles has been proved. The seam averages about 3 feet, of which 22 to 23 inches yield over 65 per cent. of volatile hydrocarbons. Under the shale is a layer of sandstone, and then 20 inches of good steaming coal.

**Petroleum in California.**—The most important mining operations in Los Angeles County are connected with petroleum, of which 979,695 barrels were produced in 1895. Up to the present, most of the oil is obtained from a stratum of sand about 40 feet in thickness, and carrying 10 per cent. of oil, under the town of Los Angeles. Santa Barbara County also contains a considerable number of wells, and produced nearly 17,000 barrels, and Ventura County has also produced oil. In the latter county tunnels are driven to obtain the oil, and are ventilated by a species of trompe.‡

At the Occidental Tunnel in Santa Barbara County oil has been found in fissures in a blue sandstone.§

F. Salathè || finds from 0·75 to 3·5 per cent. of nitrogen in oils from Ventura County, California, and has identified a number of bases of the pyridin and chinolin series heretofore only found in distillation products

\* *Canadian Mining Review*, vol. xvi. No. 1, p. 2.

† *Australian Mining Standard*, October 1, through the *American Manufacturer*, vol. lx. p. 46.

‡ Thirteenth Annual Report of the Californian State Mining Bureau, 1896, pp. 570-593.

§ *Engineering and Mining Journal*, vol. lxiii. p. 49.

|| Thirteenth Annual Report of the Californian State Mining Bureau, 1896, pp. 656-661.

of animal matter. In his opinion this proves the animal origin of petroleum. The chemical constitution and hydrocarbon series of Ventura and Los Angeles crude oils are then dealt with, and a number of fractional distillations of various Southern Californian crude oils are appended. The bearing of these researches on the refining methods is then shortly considered, and fuller details are promised.

**Bituminous Rock in Kentucky.**—M. Morris\* states that the bituminous rock in Kentucky is found in the Chester group of the Sub-Carboniferous rocks along the eastern and southern edge of the western coalfield. The impregnated rock is not found in distinct seams, but rather as lenses attaining up to 10 feet thickness in the centre, and then sometimes shades off into the surrounding sandstone, and at other times breaks off abruptly. It has been found necessary to strip off the overburden to work these deposits economically.

**Asphalt.**—There are in California a considerable number of workings for asphalt and bituminous rocks, and of these particulars have recently been published. At one working in San Luis Obispo County the bituminous rock is 30 feet in thickness. Here the rock is passed through a crusher, and then into a horizontal cylinder 18 feet long and 38 inches internal diameter, where it is warmed by steam and mixed to render it more uniform and less bulky. Poor rock is used as fuel. At Las Conchas mines in Santa Barbara County, bituminous sand, averaging 25 feet in thickness, lies under 6 to 8 feet of cover. The latter is removed by hydraulicing, and then the bituminous sand is excavated with hot spades, and taken to a revolving steam-jacketed mixer. Thence it falls into boiling water, in which the sand settles whilst the maltha floats. Refined products amounting to 75 tons per twenty-four hours is produced by the labour of thirty men in the mine and thirty in the works. At the Pacific Asphalt Company's mines crude petroleum is used to aid the extraction.†

In a recent consular report it is stated ‡ that large deposits of asphalt are found some 300 miles from Matamoros, Mexico. About twenty wells from which mineral tar was flowing were seen, and asphaltic deposits cover about twenty square miles of country.

Having had occasion to study a large number of rocks more or less

\* *Engineering and Mining Journal*, vol. lxiii. p. 46.

† Thirteenth Annual Report of the Californian State Mining Bureau, 1896, pp. 35-45.

‡ *Engineering and Mining Journal*, vol. lxii. p. 610.

impregnated with asphalt, and notably specimens from the Val de Travers in the Jura of Neuchâtel, Stanislas Meunier\* sought a rapid and at the same time correct method for determining their asphalt contents ; and he considers that he has found one in the use of carbon bisulphide, which is a remarkable solvent of this substance. This reagent, which appears not to have been previously used for this purpose, completely takes the colour out of the Val de Travers asphalt rocks, the remainder only showing slight traces of bituminous matters on the application of heat, while the evaporation of the solution leaves behind pure asphalt.

L. A. Linton† gives a few more instructions as to the assay of asphaltum. In estimating the moisture, the temperature should not exceed 50°, and the drying is best effected by heating the sample in a current of dry air ; the dried sample is then tested as directed. It is now recommended to fraction the asphaltene by estimating the portion soluble in boiling turpentine and that soluble in chloroform only. After removing the petrolene, the residue on the filter is digested in boiling turpentine until the filtrate is colourless ; the filter is then washed with alcohol and dried at 100°. If a black semi-liquid substance separates from the mass, the extraction with turpentine should be repeated ; the residue on the filter is finally exhausted with chloroform to remove the portion undissolved by the turpentine. "Aged" varieties of asphaltum contain a larger proportion of asphaltene, but the fraction soluble in turpentine is smaller, whilst that soluble in chloroform is larger.

**Trinidad Pitch.**—S. F. Peckham and L. A. Linton ‡ have made analyses of the pitch found in and near the Pitch Lake of the Island of Trinidad. The pitch found within the lake and also that outside have very much the same composition, and in all cases the pitch is fully saturated with moisture, usually containing some 25 to 30 per cent. About 38 per cent. of the residue is sand, the rest is bitumen and fragments of vegetation and disorganised cellular tissue. The pitch which rises in the middle of the lake has a vesicular structure. When freshly dug its colour is brown, but if left in the sun it soon darkens, finally becoming bluish-black. A large mass, when placed in bright sunshine, will melt to a thin pellicle upon the exposed surface, and retain the larger part of the water at a temperature sufficient to remove every trace of water if it were dried in the shade. Numerous analyses are quoted.

\* *Comptes Rendus de l'Académie des Sciences*, January 1, 1897.

† *Journal of the Chemical Society*, vol. lxxi. and lxxii. p. 79.

‡ *American Journal of Science*, vol. i. pp. 193-207.

**Estimation of Gases Produced by the Combustion of Petroleum.**—According to R. Kissling,\* a small lamp, with a reservoir capable of holding about 100 grammes of oil, is fitted with a lamp-glass made of hardened glass, the top of which is drawn out and bent so that it may be connected with a series of absorbing tubes. By means of a current of air the products of combustion are first passed through a U-tube 200 millimetres long, filled with glass beads moistened with a 5 per cent. solution of potassium permanganate. The gases then again pass through a nitrogen bulb also filled with permanganate solution, and finally through an empty bulb. When the combustion is over the tubes are rinsed, the liquid cleared by boiling with hydrochloric acid, and the sulphuric acid estimated with barium chloride in the usual manner. The air in the room should, of course, be free from any sulphurous vapours.

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#### VI.—*NATURAL GAS.*

**Natural Gas in California.**—In California natural gas is found in eight counties, but is only utilised in three. The chief development is in San Joaquin County.†

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#### VII.—*ARTIFICIAL GAS.*

**Mond Gas-Producer Plant.**—At a meeting of the Institution of Civil Engineers, H. A. Humphrey described the extensive Mond gas-producer plant at Winnington, where cheap bituminous coal is used, and no less than 90 lbs. of sulphate of ammonia are recovered per ton, or 70 per cent. of the total nitrogen in the fuel. The essence of the process lies in the extent to which regeneration is pushed. Water which has been used to cool the gas is used to heat and saturate the air for combustion, and this air is further heated by leading it through annular passages surrounding the gas take-offs. Very full experiments were made by the author with this plant, and the results showed that for every ton of fuel fed into the producer about  $2\frac{1}{2}$  tons of steam and three tons of air were blown through the grate, the mixture being at a temperature of  $250^{\circ}$  C. Of this steam one ton was furnished by the system of regeneration, and  $1\frac{1}{2}$  ton was added as exhaust steam from various engines and pumps.

\* *Chemiker Zeitung*, vol. xx. p. 199.

† Thirteenth Annual Report of the Californian State Mining Bureau, 1896, pp. 567-569.

Over half a ton of steam was decomposed in passing through the hot fuel, and nearly  $4\frac{1}{2}$  tons of gas were formed from one ton of coal, equal to about 160,000 cubic feet at ordinary atmospheric temperature. This gas had a calorific value of 81 per cent., calculated on the calorific value of the ton of fuel gasified, and the net cost, including, fuel, labour, &c., was less than five shillings at the present price of sulphate of ammonia. When Mond gas was burnt with air, both in the cold state, the resulting temperature was  $1150^{\circ}$  C., but with regeneration it was possible to reach very much higher temperatures. The first circular Mond producer had been started to work in September 1893, and for three years there had been no repairs either to the brickwork lining or to the producer proper.

In dealing with the application of the Mond producer plant, the author was able to give the actual figures obtained at Winnington, where Mond gas had been applied to the following purposes :—(1) Furnace and boiler heating ; (2) the manufacture of steel ; (3) motive power. In each case great economy arose from its use. In a Babcock-Willcox boiler the gas from one ton of fuel evaporated over seven tons of water from and at  $100^{\circ}$  C., and the gas had proved eminently suited for use in the manufacture of steel.

In 1894 the author had carried out the first experiments in the application of Mond gas to the generation of mechanical power. The trial of a 25 nominal horse-power Otto-Crossley gas-engine gave most satisfactory results, 2166 horse-power hours being obtained per ton of fuel in the producers, the thermal efficiency of the engine being 23·8 per cent. A much larger engine was being erected to drive a dynamo with an output of 75,000 watts. In order to better realise what might be accomplished in the way of cheap power-supply, the case of a 10,000 horse-power central station was considered to show the design of the gas-producers and recovery plant suitable for providing the necessary gas for this power. A summary of the advantages to be derived from central power-stations on these lines concluded the paper, and gave rise to some discussion, in which W. H. Preece very clearly stated that, in present circumstances, it was cheaper to convey coal for long distances than to carry the corresponding power as electric current, but he added that possibly it might be still cheaper to turn the coal into gas, which may be taken through pipes over long distances, as is done with natural gas in America.

A number of photographic and other illustrations have appeared \* of the Loomis gas plant at Bridgeport, Connecticut. The capacity is five

\* *Iron Age*, vol. lviii. pp. 949-953.

million cubic feet of gas daily from eight Loomis producers, 9 feet in diameter and 15 feet in height. The fuel-bed in the producer is 8 feet deep. Producer-gas is made for five minutes, and then steam is turned on for five minutes. The producers are worked in pairs, and when steam is on, the current passes up one and down the other, so as to fully utilise the volatile matters of freshly added coal. The boilers, holders, purifiers, and other plant are described.

Two Mond gas-producers are also at work at Halifax, Nova Scotia, and some particulars of the plant have been given.\*

**Gas-Producers.**—According to A. H. Sexton,† gas-producers are now all worked with forced draught, and natural draught working is obsolete. Those in use may be divided into three classes—those with bar bottoms, with solid bottoms, and with water bottoms. The first are not much used, owing to the fall of unconsumed carbon through the bars and the difficulty of removing ashes. Nearly all solid-bottom producers have to be stopped periodically for cleaning, but Taylor's revolving-bottom producer obviates this difficulty. Wilson's producer is also referred to. In this country water bottoms are largely used, and the author illustrates two forms which are designed to facilitate the removal of ashes. In Dawson's producer the circular body stands on short columns in a circular water-tray, so that access can be had from all sides. A circular  $\Gamma$ -section girder which carries the masonry dips into the water and forms a seal, and a central tuyere pipe supplies air. The second form, due to E. J. Duff, has a rectangular body and a sloping grate standing over a rectangular water-trough. A ridge of masonry runs centrally across the trough and carries the  $\Lambda$ -shaped grate, beneath which steam is introduced. Ash is removed from both ends. These producers gassify from 20 to 30 lbs. of coal per square foot of producer bottom per hour.

As a means of utilising the culm or waste small anthracite, N. W. Perry ‡ advocates its conversion into gas which is to be used in gas-engines. This method of conveying power is compared with electric transmission.

In enriching water-gas by carburetting it with oil, a certain amount of tar is formed, and A. S. Miller § describes the best methods of separating this from the scrubber water.

\* *American Manufacturer*, vol. lix. p. 769.

† *Journal of the West of Scotland Iron and Steel Institute*, vol. iv. pp. 128-134.

‡ Paper read before the Anthracite Coal Operators' Association, through the *American Manufacturer*, vol. lix. pp. 730-731.

§ Paper read before the American Gas Light Association, through the *American Manufacturer*, vol. lix. p. 805.

## VIII.—COAL-MINING.

**Deepest Borehole.**—According to C. Zundel,\* the deepest borehole yet put down, that at Paruschowitz, near Rybnik, in Upper Silesia, was undertaken for establishing the Government rights to certain coal deposits. Whereas the depth of the Schladebach boring near Leipzig did not exceed 1748 metres (955 fathoms), the Paruschowitz hole attained 2003·34 metres (1095 fathoms). The greatest difficulty in these deep boreholes consists in the enormous weight attained by the boring rods. In the case under notice the weight was reduced by substituting steel for iron; and yet at the depth of 2000 metres (1093 fathoms) the total weight was 13·707 tons.

Recent improvements in deep boring are described by E. Gad.†

**Mining at Great Depths.**—In a paper read before the Society of Arts, Bennett H. Brough ‡ gave the accompanying list of the more important deep shafts, illustrating the depth to which mine workings up to the present time have penetrated:—

United States—	Deep Shafts.	Feet.
Red Jacket, Calumet and Hecla, Lake Superior . . . . .	4,900	
Tamarack, Lake Superior . . . . .	4,450	
Yellow Jacket, Comstock, Nevada . . . . .	3,123	
California Mine, Colorado . . . . .	2,260	
Grass Valley, Idaho . . . . .	2,182	
Kennedy Mine, Jackson, California . . . . .	2,150	
Pottsville shaft (disused), Philadelphia and Reading Coal and Iron Company . . . . .	2,000	
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Belgium—		
Products Colliery, Mons . . . . .	3,937	
Viviers shaft, Gilly . . . . .	3,750	
Viernoy shaft, Anderlues . . . . .	3,300	
Marchienne Colliery . . . . .	3,117	
St. André shaft, Poirier Colliery, Charleroi . . . . .	3,100	
Ciply Colliery, Mons . . . . .	2,950	
Houyoux Colliery, Centre . . . . .	2,300	
Marihaye Colliery, Liége . . . . .	2,100	
Average depth of all Belgian collieries . . . . .	1,420	
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Austria-Hungary—		
Adalbert, Przibram, Bohemia . . . . .	3,672	
Maria, Przibram . . . . .	3,281	
Anna, Przibram . . . . .	3,100	
Franz-Josef, Przibram . . . . .	2,900	
Procopi, Przibram . . . . .	2,900	
Einigkeit, Joachimsthal, Bohemia . . . . .	1,750	
Amalia, Schemnitz, Hungary . . . . .	1,750	

\* Société Industrielle de Mulhouse.

† Dingler's *Polytechnisches Journal*, vol. cccii. p. 228.

‡ *Journal of the Society of Arts*, vol. xlv. pp. 57-75.

Great Britain—	Deep Shafts	Foot.
Pendleton, Manchester (workings)	. . .	3,474
Ashton Moss, Manchester (workings)	. . .	3,360
Astley Pit, Dukinfield (workings)	. . .	3,150
Dolcoath Mine, Cornwall	. . .	2,582
Rose Bridge Colliery, Wigan	. . .	2,446
Cook's Kitchen, Cornwall	. . .	2,436
Harris' Navigation, Pontypridd	. . .	2,367
Cadoby Main Colliery	. . .	2,250
Bickershaw Colliery, Leigh	. . .	2,210
Moss Collieries (No. 4 pit), Wigan	. . .	2,205
Astley Pit, Dukinfield (shaft)	. . .	2,058
Niddrie, Portobello, N.B.	. . .	2,010
Wearmouth Colliery	. . .	1,722
Loanhead Colliery, Shotts Iron Company	. . .	1,700
 Victoria—		
Lansell's, Bendigo	. . .	3,902
Lazarus, Bendigo	. . .	3,024
Magdala, Stawell	. . .	2,409
Twenty-five gold-mines exceed	. . .	2,000
 Germany—		
Kaiser Wilhelm II., Clausthal, Harz	. . .	2,960
Einigkeit, Zwickau, Saxony	. . .	2,620
Samson, St. Andreasberg, Harz	. . .	2,566
Frieden Colliery, Olsnitz, Saxony	. . .	2,515
Concordia Colliery, Olsnitz, Saxony	. . .	2,420
Hansa Colliery, Huckarde, Westphalia	. . .	2,330
Maria Colliery, Honigen, Westphalia	. . .	2,300
Camphausen Colliery, Saarbrücken	. . .	2,296
Freiberg, Saxony (maximum depth)	. . .	2,060
 France—		
Montchanin Colliery, Le Creuzot	. . .	2,300
Treuil Colliery, Saint Etienne	. . .	2,034
Hottinguer shaft, Epinac	. . .	2,000
Rouchamp Colliery, Haute-Saône	. . .	1,870
 South Africa—		
Robinson Deep, S.A.R.	. . .	1,991
Nourse Deep	. . .	1,578
Crown Deep	. . .	1,321
Langlaagte Deep	. . .	1,302
Jumpers Deep	. . .	1,260
Kimberley Mine, Cape Colony	. . .	1,261
De Beers Mine	. . .	1,097
 Norway—		
Kongsberg Silver Mine	. . .	1,900

The results here recorded afford clear evidence that a great many of the difficulties which were formerly connected with the sinking of deep shafts have now disappeared. The valuable inventions and appliances available to the mining engineer have rendered such sinking operations easy and comparatively inexpensive. It therefore appears

that no considerations of a mechanical nature need limit the prospective depths of shafts.

The elements needing consideration regarding the limits of depth in mining are:—(1) The decreasing capacity of deep shafts; (2) the increase in pressure; (3) the increase in temperature; (4) the increase in expenditure. These were discussed in detail, and the following recent observations on the increase of temperature were cited:—

	Depth.	Increase in Temperature.	Observer.
	Feet.	Feet for 1° F.	
Calumet and Hecla, Lake Superior .	4,580	223·7	Agassiz.
Rand Victoria borehole, Transvaal .	2,500	82	Hamilton Smith.
Port Jackson borehole, New South Wales }	2,929	80	E. David and E. F. Pittman.
Wheeling oil well, West Virginia .	4,462	71·8	Hallock.
Dolcoath Mine, Cornwall .	2,124	70	Josiah Thomas.
Schladebach borehole, Prussia .	5,734	65	Huyessen.
Paruscowitz borehole, Upper Silesia .	6,573	62·1	Koebrich.
Comstock lode, Nevada .	2,230	33	G. F. Becker.

**Shaft-Sinking.**—In a review of recent progress in mining, M. Leproux \* discusses the new methods of sinking shafts. The Poetsch process has been employed in twenty instances, of which the most important is that at the Anzin Collieries, where the sinking by freezing occupied ten months, and cost 2500 to 3000 francs per running metre. This process has also been successfully applied in driving a tunnel at Stockholm, and in repairing the foundations of a lift at Fontinettes. Another process of recent introduction is that of Honigmann, which has been employed with success in Holland.

The occurrence of fire-damp during the sinking of the Schürenberg shaft at the Ewald Colliery near Herten is noted by Von Velsen,† and the recent improvements in shaft-sinking in aqueous strata are discussed by Riemer.‡

An important sinking was started on 30th March last, for the third plant of the Sandwell Park Colliery. Partly owing to the existence of faults, and partly to concealed ridges of Silurian rock which cut out the coal, there are several pieces of ground, amounting in area to 1000 acres, that cannot be worked from the present shafts. The new shaft will be sunk in the angle between one of the Silurian banks, described

\* *Bulletin de la Société d'Encouragement*, 5th Series, vol. i. pp. 1581–1610.

† *Glückauf*, vol. xxxii. p. 893.

‡ *Zeitschrift des Vereines deutscher Ingenieure*, vol. xl. p. 1461.

by H. W. Hughes\* before this Institute, and the Oxhill fault, at a sufficient distance from both to strike the coal, and, if it is successful, the second shaft will be sunk on the fault, so as to work the seam on both sides of it. In order that the work may be pushed on with expedition, and that the colliery may be opened up as quickly as possible, permanent surface plant is to be laid down with compound winding and pumping engines.†

The sinkings that were being prosecuted with such vigour to open up the coal-seams in Kent near Dover have met with a most unfortunate interruption. The "Brady" pit was down about 320 feet, but had been allowed to fill with water until the pumps arrived. In the meantime, the second or "Simpson" pit was being carried down, and had nearly passed through the clay over the greensand, when water and sand burst in from the lower porous strata without the slightest warning. Fourteen sinkers were employed at the bottom, and of these eight were drowned. Since that date (March 6) the pumps have arrived, and have been put to work, and sinking has been resumed.

J. Hastie ‡ shortly describes the sinkings at Whistleberry Colliery, Hamilton. One shaft is 1080, and the other 1041 feet deep. Both are rectangular, 21 by  $6\frac{1}{2}$  feet inside the woodwork, and divided into four compartments. During sinking, water was caught in lodgments and raised by a water-barrel. The surface plant of the colliery is also described. A section of the strata passed through is appended.

In a Presidential Address H. W. Martin § gives some particulars of sinkings made within the last few years in South Wales. Amongst these are two pits at Aberdare Junction, 740 yards deep, 20 feet in diameter in the clear, and lined with a minimum of 12 inches of brick-work. Four wooden girders, 100 feet long and 6 feet deep, were laid on transverse baulks to receive the sinking plant. The first 34 yards were sunk through alluvial deposits, and six yards down in the rock iron curbs were laid, and walling 3 feet thick was carried to the surface. Perforated iron blocks were laid in to temporarily drain off the water. Between 90 and 130 yards iron tubing was put in to hold back a spring. The curb was of very irregular form, as shown by a plan. The pumping plant for feeders encountered below is also described.

\* *Journal of the Iron and Steel Institute*, 1895, No. II. p. 22.

† *Colliery Guardian*, vol. lxxiii. p. 729.

‡ *Transactions of the Federated Institution of Mining Engineers*, vol. xii. pp. 622-631.

§ *Proceedings of the South Wales Institute of Mining Engineers*, vol. xx. pp. 2-23, with two plates.

**Enlarging a Shaft.**—H. E. Maltby \* describes the enlargement of a shaft at Lidgett Colliery without interruption of coal-winding. Until recently there were two 7-foot shafts 510 feet apart, with a single cage in each, worked from the same drum placed midway between the shafts. The shaft, 225 feet deep near the screens, was enlarged to have a rectangular section, and the air pipe, rising water main, and electric cables were not removed during the process. A wooden cover the size of the old shaft was placed over the cage and used as a platform at night-time when sinking was proceeding, and was removed in the daytime for winding. Powder was used for blasting. A separate engine was used for the kibble, and the work was completed in four months.

**Winding Engines.**—H. Bramwell † describes the compound winding engine at the Great Western Colliery Company's Tymawr pit, and gives some notes on its comparative steam economy. It is of the horizontal type, twin compound, with two steam-jacketed cylinders, one on each side of the drum. Their diameters are 32 and 48 inches and stroke 5 feet. Valves are double-beat Cornish equilibrium valves. Steam pressure is 120 lbs. The drum is cylindrical, 18 feet in diameter. The shaft is 1440 feet in depth, time of winding 50 seconds, and maximum speed of winding about 60 feet per second. The total load is nearly 9·7 tons. The steam used per hour per indicated horse-power is given as 26 lbs., and particulars are given of steam consumption in other engines to show the saving obtained.

C. Volk ‡ describes, with the aid of illustrations, various improvements which have been introduced at their mines by the Salgó-Tarján Company. These include a compound winding engine and various arrangements on Geber's patents for winding, sinking, &c.

W. D. Wight § describes an automatic variable expansion gear applied to balanced slide-valve winding engines. Two expansion valves are formed as hoops sliding on the main valve, and can close the steam passages through it. Each has a separate spindle connected to the main spindle through toggle joints, whose position is controlled by a stop regulated by a governor.

\* *Transactions of the Federated Institution of Mining Engineers*, vol. xii. pp. 642-644, with plate.

† *Ibid.*, pp. 282-293, with two plates.

‡ *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xlv. p. 88, with illustrations.

§ *Transactions of the Federated Institution of Mining Engineers*, vol. xii. pp. 279-281, with one plate.

There are many instances in mining practice where a gas-engine makes an efficient and cheap power producer. The gas-engine may, according to the *Colliery Engineer*, be economically used at collieries for winding and pumping from dip workings distant from the main openings, for running isolated ventilating machinery, and for isolated pumps for water supply at mines where electric plant is unavailable.

**Winding Appliances.**—H. W. Hollis \* describes a spring coupling for winding ropes. The ends are connected by links held apart by a spring which is compressed by the load.

The Hahn method for the prevention of over-winding, and the Jet-schien apparatus for ensuring a definite maximum velocity in winding not being exceeded, are briefly described. †

Safety appliances for winding engines are also described by Baumann. ‡

The first safety catch is said to have been invented fifty years ago by Conrad Büttgenbach, who died in 1893. § He was then mine manager at the Six-Bonniers Colliery, Seraing. In 1846 he made the model of an apparatus of this kind, and this is still in existence at the Mining Museum at Clausthal. It was first introduced at the Barbara shaft, and shortly afterwards it resulted there in the saving of seven miners who were in a cage when the rope broke at bank.

**Wire Ropes.**—At a meeting of the Engineering Association of the South at Nashville, Tennessee, a paper was read by W. Hewitt on the effects of bending on wire rope. In the course of the discussion, Calhoun mentioned the interesting practice of the miners at the Whitwell mines in getting down the 1200 feet from the mouth of the mine to the village. This is done by means of a “horse,” which is placed astride one of the rails of the incline, and sitting down on it, they use their heels, placed on the rails in front of them, as a brake, and the hand, protected by a leather palm and placed on the haulage rope, serves to steady them. The descent is effected at speeds varying from thirty to sixty miles an hour.

An account is published by K. Habermann || of an investigation of the cause of fracture of a winding rope at the Hansa Colliery, near

\* *Transactions of the Federated Institution of Mining Engineers*, vol. xii. pp. 182-185, with illustration.

† *Sächsisches Jahrbuch*, 1896, through *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xlvi. p. 159.

‡ *Glückauf*, vol. xxxii. p. 820.

§ *Revue Universelle des Mines*, vol. xxxvi. p. 124.

|| *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xliv. pp. 635-637.

Huckarde. Winding was effected from a depth of 2178 feet. The rope was round, and of hard crucible steel wire, having a tensile strength of 95·2 tons per square inch. The total stress on the rope when fully loaded was 14·359 metric tons. The accident was found to be due to the fracture of a roller over which the rope passed, and to the sudden jerk resulting from this.

**Shaft Fences.**—S. Watson \* describes the pit-top safety fencing used at New Hucknall Colliery shaft when men are being wound. The cage has three decks, and ten men ride on each of the two upper ones. Balanced arms on both sides of each deck are closed simultaneously by the banksman in charge of the middle deck before the engineman is signalled. Ordinary protection bars lifted by the cage are used when winding coal.

**Safety Props for Winding.**—C. S. Smith † describes safety props which have been used at Shipley Collieries for supporting cages in the head-gear of pits in case the safety hook or bridle chains fail to support it after an over-wind. Swinging props are carried by spring bearings so that when loaded they settle on to the frames. The front edges of the props are wedge-shaped, and terminate at the bottoms in beaks so as to bring the cage gradually to rest, and to hold it firmly if it falls. The props are held out of action by trigger levers, which liberate them when the ascending cage strikes tappets connected to the triggers. At the same time stops are liberated and fall down behind the props, so as to give them a solid abutment.

**Steel Head-Frame.**—W. Wilkins ‡ describes and illustrates the steel head-frame at the Morewood shaft of the South-West Connellsburg Coke Company. The shaft is notable from the fact that it is the first sunk in the Connellsburg coke region, all the other mines being worked by adits or inclines. The old wooden head-frame having become insecure, it was decided to erect over it a more modern steel structure with bins holding 700 tons of coal.

**Underground Haulage.**—R. S. Williamson § describes the underground haulage at Cannock and Rugeley Collieries, giving details of the

\* *Transactions of the Federated Institution of Mining Engineers*, vol. xii. pp. 122-123.

† *Ibid.*, vol. xii. pp. 564-67, with one plate.

‡ *Colliery Engineer*, vol. xvii. pp. 297-298.

§ *Transactions of the Federated Institution of Mining Engineers*, vol. xi. pp. 564-571, with two plates.

various systems employed, which include self-acting inclines, main and tail rope and endless rope driven by ropes brought down from the surface, electric and compressed air motors. In one district recently opened out small installations are used to bring the coal to a centre.

S. Diescher \* deals with the engines, drums, and ropes used on inclined planes, and gives some tests of the ropes.

W. Galloway † deals with the cost of secondary haulage, that is, the haulage between the working face and the receiving end of the main haulage system, a subject to which comparatively little attention has been paid. The items to be determined are the distance of each face from the siding, the weight moved, and the amount paid. These were determined by the author for two weeks at Llanbradach Colliery, near Cardiff, in a 3-foot seam, dipping on the average 1 in 24. Self-contained, semi-portable engines, worked by compressed air, were exclusively employed, and their construction is described and illustrated. During two weeks the cost per ton worked out at 2·796 pence for 359 yards average, and 3·642 pence for 575 yards average. The exact cost in a large Welsh colliery for horse-haulage is given as 8·97 pence per ton, and in another case as 15 pence per ton for an average distance of 500 yards. A lengthy discussion produced many other figures of cost from different parts of the country, and many of the figures for horse-haulage much lower than those above are given. The author himself also quoted 4·31 and 5·572 pence per ton as the cost in Durham for small engines and pony-putting respectively over 581 yards. The cost of the plant is also given.

At the Fuchs Colliery, near Weissstein, in Lower Silesia, a rope-haulage plant, on the Stoltz continuous system, has recently been laid down. In this the empty waggons passing along the main haulage-road are constantly being replaced by the laden ones from the cross-roads. The system is described by the aid of an illustration. It is stated to possess numerous advantages.‡

R. Street § briefly reviews the different methods of underground haulage, and mentions main rope, main and tail rope, endless rope, compressed air and electric locomotives, and also mule-haulage. Main

\* *Proceedings of the Society of Engineers of Western Pennsylvania*, vol. xii. pp. 234-265; *Iron Age*, vol. lviii. pp. 1083-1084, 1141-1144.

† *Transactions of the Federated Institution of Mining Engineers*, vol. xii. pp. 257-278, with one plate.

‡ *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xliv. pp. 682-683, one illustration.

§ Paper read before the Western Pennsylvania Central Mining Institute, through the *American Manufacturer*, vol. lx. pp. 48-49.

and tail rope appears to be most extensively used in Western Pennsylvania.

J. Piggford \* describes the rope-haulage plant driven by electromotors at the Pleasley Colliery, which has been largely increased since it was started in 1891. Now 24,732 feet of rope are driven from main motors, and the output of the pit is 1700 tons daily. The results of tests of the efficiency are given, together with the costs as compared with horse-haulage.

Illustrations of the Thofehrn electric mine locomotive have recently been published.† With a draw-bar pull of 1000 lbs., its length is under 6 feet, and it will pass through a tunnel 4 by 3 feet. It takes current from an overhead conductor, and carries two motors with double reduction spur-gearing. The gauge is 20 inches, and the wheel base 22 inches.

E. Boissier ‡ gives numerous details regarding the employment of horses for underground haulage in the Gard coalfield.

**Laying Out Pit Bottoms.**—W. Stewart § discusses the laying out of pit bottoms, and points out the factors that have to be taken into consideration. After settling the size of the tubs and the shaft, the bottom should be so planned that all the coal is caged at one landing. The direction of the main headings is controlled by the area of the property and by the dip of the seam, but it is very important that the gradients should be suitable for handling the full and empty tubs. Heavy permanent way and solid brick arching should be put in. The question of bellringing the shaft or of side-roads is discussed in relation to the transference of tubs from one side to the other. The minimum radius of a shaft pillar is given as 150 yards for any depth up to 200 yards, with an increase of 25 yards for each 50 yards of depth, up to 300 yards for 500 yards of depth or over. Stables and water lodgment are referred to, and also the lighting. Finally, a description and plan are given of the bottom of the Vivian Pit, Abertillery, laid out by the author.

**Electricity in Mining.**—F. C. Whitmore || describes a successful electric winding and pumping plant at the Maltby Mine of the Lehigh

\* *Transactions of the Federated Institution of Mining Engineers*, vol. xii. pp. 633-641, with plate.

† *Engineering and Mining Journal*, vol. lxiii. pp. 66-67.

‡ *Bulletin de la Société de l'Industrie Minérale*, vol. x. p. 295.

§ *Proceedings of the South Wales Institute of Engineers*, vol. xx. pp. 122-133, with plate.

|| *Colliery Engineer*, vol. xvii. pp. 281-283.

Valley Coal Company, near Wilkesbarre, Pennsylvania. The electric plant comprises an engine and dynamo, both situated at the surface near the boilers, the current being transmitted by wires to electric motors driving the pumping and winding drum underground. The wires are run underground on 30 feet insulated poles, and are then suspended down boreholes 350 feet deep specially drilled for the purpose.

At the Ilse brown coal mine, near Bückgen, in the West Cottbus mining district, a central power station has been laid down. This is provided with two compound engines, each of 400 to 450 horse-power, to drive the dynamos. These deliver a three-phase rotary current of 2000 volts tension. The leads are above ground, and consist of separate wires, a cable lead being only used to the motor in the mine which drives the cable-way. Transformers are employed for the lighting current, and for the smaller motors used for briquetting, &c. A wire ropeway and a second shaft pump are also to be driven from this central station.\*

S. F. Walker † has continued his description of the applications of electric light and power in collieries.

T. W. Sprague ‡ describes the central electric power station of the Davis Coal and Coke Company in West Virginia. Only one of three dynamos is at present installed, and this can supply three-phase alternating current at 500 volts. Power is used for driving coal-cutters of the chain type and for elevators.

R. Holiday § points out that when electric lighting is used at mines, the generating plant can be used for other purposes, especially during the daytime, when the surface lights are not required. At one colliery in Yorkshire this has been done with success, and the efficiency of the plant thereby increased. Some plants are then described in which this system is carried out at Acton Hall Colliery and elsewhere. Steam-turbines coupled direct to the dynamo are used in one of these plants. Polyphase motors, cables, and fuses are also considered.

**Relative Merits of Compressed Air and Electricity.**—G. E. J. M'Murtrie || discusses the comparative advantages and disadvantages of

\* *Zeitschrift für des Berg-, Hütten- und Salinenwesen im preussischen Staate*, vol. xliv. p. 204.

† *Colliery Guardian*, vol. lxxiii. pp. 310, 396, 502, 593.

‡ *Engineering and Mining Journal*, vol. lxiii. pp. 91-92.

§ *Transactions of the Federated Institution of Mining Engineers*, vol. xii. pp. 2-15, with one plate.

|| *Iron and Coal Trades Review*, vol. liv. pp. 161-164.

steam, compressed air, and electricity for power purposes in coal-working, and shows that rope-haulage plants, driven by steam-engines at the surface or underground, are more economical than similar plants driven by either compressed air or electricity; yet that, when the time arrives for the haulage to be extended, and for subsidiary haulage to be put down in-bye, electricity and compressed air only can be used. Also, that of the two, electricity, on account both of its greater efficiency and its reduced first cost, is then to be preferred. For similar and other reasons, it is considered that electricity should be adapted for both pumping and coal-cutting.

J. L. Thomas \* also deals with this subject. Steam is most economical for short distances, but condensation gives much trouble, and many disadvantages appertain to the use of underground boilers. Compressed air is expensive, but it is well suited for use where water spray for laying dust is required. Electricity is more economical, but less safe, and the cables are liable to give much trouble. It should be used with a constant load, and altogether it is most adaptable to various circumstances.

C. C. Ellison † gives illustrations of the economical use of steam carried down the shaft. The losses in air-compressing plant and their cost are dealt with, and the forms of pipes and joints are illustrated. Electrical transmission is also discussed. It is concluded that both compressed air and electricity have their own spheres, the former giving safety in fiery mines with lower efficiency, whilst the latter gives higher efficiency at less cost. Their relative efficiencies may be given as 45 and 65 per cent of the steam used. Cost of air-compressing plant is given as about 33 per cent. more than electric plant, and the working of the latter shows a saving of 8 to 10 per cent. in its favour.

E. K. Scott ‡ also deals with these subjects, and pays especial attention to coal-cutting by machinery.

In connection with the subject of the transmission of power, there has been recently published a vast amount of literature dealing with the advantages and uses of compressed air, and it may be of interest to refer to one or two of these papers. A. de W. Foote § describes a water-power and compressed air transmission plant for the North Star Mining Company, Grass Valley, California. Water supplied from a pipe-line at a static pressure of 325 lbs. is supplied to a Pelton wheel

\* *Iron and Coal Trades Review*, vol. liv. pp. 225-226.

† *Ibid.*, pp. 259-260, 293-294, 333-335, 365-367.

‡ *Ibid.*, pp. 505-506, 539-540, 573-574, 609-610, 641-642.

§ *Transactions of the American Society of Civil Engineers*, vol. xxxvi. pp. 171-196, with plates.

18½ feet in diameter, which drives a duplex compound air compressor with cylinders 18 and 10 inches in diameter and a stroke of 24 inches. They run at 110 revolutions, taking 283 horse-power, and deliver air at 90 lbs pressure. The air is taken through a 6-inch lap-welded pipe to drive a 100 horse-power hoisting engine, a 75 horse-power pump, and other machinery. The air is heated before use.

R. Jenkins \* deals with the application of compressed air to traction, to which he thinks that it is especially applicable, particularly when the air is preheated, as in the Mekarski system, by causing the air to bubble up through a tank of hot water. The economies in compression and expansion, the weight of the receivers, and other cognate matters are discussed.

The use of lightning arrestors and the comparative efficiency of compressed air and electric transmission formed the basis of a lengthy discussion on some of these papers.† It is admitted that exact data on the latter point are wanting, but there is a general tendency in existent tests to show a great preponderance in favour of electricity.

Further discussion on the economy of compressed air, and mostly in its favour, has appeared in numerous sources.‡

C. W. Shields § also deals with the recent advances in the use of compressed air, and cites a number of applications, many of which are illustrated.

L. Searing || gives the comparative results of two plants working side by side under similar conditions, one worked by electricity, and the other by compressed air.

**Mine Timber.**—E. B. Wain ¶ describes a handy appliance to be used instead of the dog and chain for drawing timber. A short but powerful lever is used to work a rack working through the block on which the lever is fulcrumed. Short lengths of chain attached to the block and the rack are connected to the prop and to a fixed point.

\* Paper read before the Liverpool Branch of the Horseless Traffic Association, through the *Automotor*, March 17, 1897.

† *Transactions of the American Institute of Mining Engineers*, 1896, Colorado meeting (advance proof).

‡ *Iron Trade Review*, vol. xxx. No. 3, pp. 14-15; *Engineering Magazine*, vol. xii. pp. 470-477; *Iron and Coal Trades Review*, vol. liv. p. 81.

§ *Engineering Magazine*, vol. xii. pp. 657-673.

|| *Electrical Engineer*, November 25, 1896.

¶ *Transactions of the Federated Institution of Mining Engineers*, vol. xii. pp. 591-595, with one plate.

J. D. Isaacs \* deals generally with the preservation of structural timber, and gives full details of the zinc chloride and creosote processes. Amongst the preservatives tried during the last century and early in this may be mentioned copperas, bluestone, nitrate of silver, corrosive sublimate, sulphate of zinc, carbonate of soda, caustic soda, arsenic, barytes, common salt, quicklime, alum, soap, resin, coal-tar, vegetable oils, fish oils, vapour of oils, powdered charcoal, and charring. Later processes are Lostal's with quicklime, Koug's with sodium carbolate, Hock's with paraffin, and Payne's with sulphate of iron and then lime-water. Many processes like the latter have been used with the object of just impregnating with one substance, and then sealing or soaking the exterior with a different material, which may form an insoluble compound with the first substance. Amongst these are soap followed by tar acids, common salt by alum, phosphate of soda by barium chloride, tannin by acetate of iron, soda or sulphate of copper by creosote and chloride of zinc, and glue by tannin. Many inventors ignore the fact that much depends on the seasoning, age, and other factors. During the past fifty years four principal methods have assumed commercial importance, of which impregnation with sulphate of copper and corrosive sublimate are gradually falling into disuse, whilst creosote and chloride of zinc hold their own. For zinc chloride the best strength of solution is between 1·5 and 2·0 per cent. The wood is first subjected to steam at 30 lbs. pressure in a closed vessel, which is then exhausted, and the requisite quantity of chloride solution forced in by a pump. The process takes seven hours. The salt is not easily washed out of the wood. As regards purity, it should contain 97 per cent. of zinc chloride. Good creosote for timber preservation should contain about 8 per cent. of tar acids, 20 of naphthalene, 30 of heavy residuum after distillation up to 600° F., consisting chiefly of anthracene and pitch, and the remainder is composed of light and heavy solvent oils. It should contain no ammonia or water, or substance soluble in water, and should be liquid at 100° F. Up to 10 to 14 lbs. should be injected per cubic foot into the steam-dried timber.

A firm at Lowell, Massachusetts, has published a pamphlet containing an interesting account of the kyanising of timber by impregnation with corrosive sublimate. The process has been in use since 1832, and in some cases timber treated in this way has been exposed for over forty years without decaying. The present price of the treatment is 32s. per 1000 feet board measure.

\* *Thirteenth Annual Report of the Californian State Mining Bureau*, 1896, pp. 647-655.

**Driving Stone Drifts.**—W. Johnson \* gives some notes on driving a long cross-measure drift from both ends to serve as a haulage and drainage road at the Braylin Domain Colliery, Cumberland. The drift is 1189 yards long, and rises 16·7 feet in that distance, meeting the seam which had been thrown down about 200 feet by two faults. Most of the rock was hard sandstone, in which Schram's percussive drills were used, whilst rotary drills were used in softer material. Gelatine and powder were used. The survey was made by a 6-inch transit theodolite reading to 20 seconds. A copy of the survey-book and calculations are given, and the work met exactly at 34·22 chains from the out-bye end in two years six weeks and three days.

The Duisburg percussion drills have been employed in driving a stone drift in slate and hard sandstone. The rate of progress was about  $3\frac{1}{2}$  times as fast as ordinary hand-drilling. The drill is described.†

**Explosives and Blasting.**—H. Hall,‡ in his paper on the cost and efficiency of safety explosives as compared with gunpowder, has collected a large amount of statistical matter dealing with this subject, and deduces the average cost per ton of coal as 0·61 penny for gunpowder and 0·92 for safety explosives. The amount of round coal yielded in each case is, however, practically the same, viz. 62·0 and 62·2 per cent. In driving galleries in stone, the high explosives show an advantage of 25 per cent. On the whole, this author regards the adoption of the "Explosion in Coal Mines Order" issued by the Government as likely to minimise the risk of explosions both of fire-damp and of coal-dust. The order above referred to is substantially as follows:§—

In all coal-mines in which inflammable gas has been found within the previous six months, and in all coal-mines which are not naturally wet throughout, on and after the 1st July 1897, the use of any explosive other than a permitted explosive, is absolutely prohibited in the roads, and on and after the 1st January 1898, the use of any explosive, other than a permitted explosive, is absolutely prohibited in every part of the mine.

Permitted explosives are to be used with nine inches of stemming, with a method of igniting not capable of firing gas, and shall be fired by

\* *Proceedings of the South Wales Institute of Mining Engineers*, vol. xx. pp. 64-70, with two plates.

† *Zeitschrift für das Berg-, Hütten- und Salinenwesen im preussischen Staate*, 1896; *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xlv. p. 55.

‡ *Transactions of the Federated Institution of Mining Engineers*, vol. xi. pp. 526-535.

§ *Colliery Guardian*, vol. lxxii. p. 1215.

a special man. Practically all the men must be removed before blasting. The permitted explosives are ammonite, ardeer powder, ballite, carbonite, dahmenite, electronite, kynite, roburite, westphalite, as given in a provisional list.

Further communications on the subject of explosives have appeared from Winkhaus,\* and these contain accounts of experiments made with the most recent explosives without stemming in the presence of fire-damp and coal-dust. Experiments with detonators were repeated in larger numbers, and other series were made with stemming and with water-cartridges. The results are given in twelve tables.

C. Pusch † considers the series of experiments to determine the behaviour of high explosives in the presence of coal-dust or fire-damp which were made at the Consolidation Colliery, Dortmund, accounts of which have already appeared. He points out that these experiments showed that the relative safety of an explosive is a function of its flaming character and explosion temperature. The experiments showed that in the case of very "safe" explosives the presence of coal-dust did not increase the danger of firing gas. Other points are also referred to.

In an official report by V. Watteyne ‡ on the use of explosives in Belgium, it is shown that black powder still forms three-quarters of the whole consumption. The quantities and proportions of high and safety explosives were as follows :—

Class of Colliery.	1893.		1894.		1895.	
	Total Quantity in Kilogrammes of High and "Safety" Explosives Consumed.	Percentage of Total Explosives Consumption.	Total Quantity in Kilogrammes of High and "Safety" Explosives Consumed.	Percentage of Total Explosives Consumption.	Total Quantity in Kilogrammes of High and "Safety" Explosives Consumed.	Percentage of Total Explosives Consumption.
Non-fiery . . .	16,700	5	18,723	6	12,473	4
Slightly fiery (1st class).	69,380	22	75,712	25	83,066	28
Decidedly fiery (2nd class).	115,573	37	123,114	40	114,588	39
Very fiery (3rd class).	23,661	85	28,169	85	21,960	90
Collieries of all classes together (totals and means)	225,314	23	240,718	26	232,067	26

\* *Transactions of the Federated Institution of Mining Engineers*, vol. xii. pp. 32-51.

† *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xliv. pp. 640-643.

‡ *Annales des Mines de Belgique*, vol. i. pp. 552-584.

After successful experiments, dahmenite A has been introduced for exclusive use at the Sulzbach Colliery near Saarbrücken.\* The smoke it produces is less than results either from dynamite or powder, while its explosive power lies between that of powder and ordinary dahmenite. The quantity of lump-coal produced by this explosive appears to be greater than that resulting from the use of westphalite. The cost of explosive per ton of coal wound proved to be as follows at the above mine :—

Explosive.	Pence.
Powder . . . . .	0·6
Dynamite . . . . .	0·6
Dahmenite . . . . .	0·7
Westphalite . . . . .	0·7
Dahmenite A . . . . .	0·6

The percentage of lump-coal resulting from the use of different explosives was as follows :—

Explosive.	Lump-Coal. Per Cent.
Powder . . . . .	50·0
Dahmenite A . . . . .	51·0
Gelatine-dynamite in water-cartridges . . . . .	44·7
Rössahlite . . . . .	46·3

The experiments which were made with lithrotite at the König Colliery in Upper Silesia gave unfavourable results, and those with spirallite showed that for equal weights it possessed the same explosive power as dynamite, but the holes must be drilled of double the diameter required when dynamite is the explosive in use. Spirallite proved readily susceptible to the action of moisture. Westphalite gave good results as compared with black powder, but it cannot be used in wet spots, and is too costly ever to replace powder in fiery mines. It did not give such good results as compressed powder, however, and per ton of coal obtained its cost proved twice as high. Guhr-dynamite tried at the König Colliery gave less satisfactory results than ordinary dynamite.†

J. von Lauer † discusses electric firing of shots from the point of view of the use of this method in fiery mines. He treats of the various systems in use, dealing with each in detail, and in conclusion trusts that

\* *Zeitschrift für das Berg-, Hütten- und Salinenwesen im preussischen Staate*, vol. xliv. p. 165.

† *Ibid.* vol. xliv.

‡ *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xliv. pp. 599–602, 610–614, 627–631, 637–640, 650–654, and 669–673, with sheet of illustrations.

this description will attract the attention of coal-miners to a method of shot-firing which is of such great value that probably, with its continued improvement, there will be achieved a close approach towards the long sought for possibility of firing shots in fiery mines without danger.

F. Winkhaus \* deals with the danger of employing safety fuses for blasting in fiery mines. Two classes of fuse are distinguished. In one the burning of the core does not destroy the outer covering, and in the other the covering partly burns away with the core. In the first kind, the gases can escape through the tube formed as the core burns, but any continuous pressure or kink closes the tube and causes it to burst, and flame may thus be given out, and sometimes the whole of the core detonates and fires the charge directly. This does not occur when the covering is partly burnt, as the gas can escape laterally, and this class is therefore to be preferred. Care must, however, be taken that sparks do not escape from the igniter or end of the fuse. Electric firing is to be preferred to all other methods.

The use of safety fuses is also discussed by Buse.†

**Coal-Cutting Machinery.**—T. B. A. Clarke ‡ describes an electric coal-cutting plant on long-wall faces in a seam 3 feet thick, holed under  $4\frac{1}{2}$  feet at the rate of 80 linear yards per shift of eight hours. Two shifts can be worked; so two machines cut 480 yards daily, producing 600 to 700 tons of coal. If the faces are 400 yards long, the gates may be placed so that the coal is filled out in three days. The engine should give 80 horse-power; a vertical high-speed engine with 14-inch cylinders and 12-inch stroke running 250 revolutions is required. The dynamo should be compound wound, giving 440 volts and 120 amperes. Separate cables are preferred to compound ones, and at the face two forty-yard lengths of strongly braided vulcanised cable give good results as regards wear. The author prefers the disc-wheel type of coal-cutting machine, and recommends that the wheel should be made in two parts to admit of easy transport. The fast-running cutter bar tends to mount in the coal in order to find the path of least resistance, and it does not bring out its own dirt. Revolving-chain cutters are short lived. The cutter wheel should run at 25 to 30 revolutions per minute, and be driven by a series wound motor capable of going up to 16 horse-power without

\* *Transactions of the Federated Institution of Mining Engineers*, vol. xii. pp. 169-178.

† *Bergbau*, vol. x. No. 6, p. 10.

‡ *Transactions of the Federated Institution of Mining Engineers*, vol. xi. pp. 492-501.

undue heating. Rails of 20 lbs. to the yard have proved strong enough for the track. An estimate of the cost of electric and air-driven plants, together with the cost of working, are given, showing a considerable advantage in favour of the former, and then particulars are given of the work done and cost in eight seams. The depth of undercut is  $3\frac{1}{2}$  or  $4\frac{1}{2}$  feet; 55 to 85 yards are cut per day, with an expenditure of 16 to 21 horse-power at the motor, and the cost for labour ranges from 0·81 to 3·30 pence per ton.

Cyrus Robinson \* discusses the comparative advantages and disadvantages of compressed air and electrically driven machines over pick-mining.

G. Gould † discusses the question whether it is profitable to work thin seams of coal by any of the types of machines now in use. One objection to the electric machines is their weight, seldom much less than 3000 lbs., and this makes them difficult to move with hand-labour in thin seams. Animal power of course requires higher headings. The weight has not been diminished though efficiency has been increased. The second objection is the length which requires that the roof shall stand well some distance back from the face. The author has had three machines cutting 96 linear feet per day in four rooms in a three-foot seam, and finds the cost rather higher than hand-labour. In a long-wall the result would probably be different, as the constant shifting would be avoided.

On the other hand, J. Hanford ‡ has found a considerable saving by the use of Ingersoll-Sergeant machines in the Darlington seam in Pennsylvania. This seam is three feet in thickness and slightly undulating, and the size of this machine gives it a great advantage on account of the ease with which it is handled in the pillar-and-stall workings. The author also discusses compressed air and electricity for transmitting power, and is in favour of the former.

At a colliery in West Virginia, according to T. W. Sprague, § seven chain-cutter machines driven electrically are installed. They cut 39 inches wide, 5 inches high, and  $5\frac{1}{2}$  to  $6\frac{1}{2}$  feet deep in  $3\frac{1}{2}$  to 4 minutes in a parting half-way up the seam which averages 6 to 8 feet in thickness.

In Ohio, according to the State Inspector of Mines, || 82 air and 82

\* *Colliery Engineer*, vol. xvii. p. 313.

† *American Manufacturer*, vol. lx. p. 14.

‡ *Ibid.*, p. 48.

§ *Engineering and Mining Journal*, vol. lxiii. pp. 91-92.

|| Report of the State Inspector of Mines, Ohio, through the *Engineering News*, vol. xxxvii. p. 17.

electric coal-cutting machines were in use in 1895, as compared with 112 and 59 respectively in 1894. Out of 13,683,879 tons of coal mined in 1895, 3,120,456 tons were mined with machinery, a gain of 564,990 tons over the previous year.

According to W. M. Brewer in *The Tradesman*, the Corona Coal Company has been the first colliery company in Alabama to introduce a complete electric plant. Jeffrey coal-cutters and motors are used. Four coal-cutters are in daily use, each with a cutting capacity of 80 to 100 tons, and a fifth machine is kept in reserve. In the Jeffrey machine, it will be remembered, the cutting is done by teeth fastened on to a chain revolving round a platform, which is forced forward by electric power as the teeth cut into the fireclay immediately under the coal. The length of the cut is 6 feet and its width 3 feet, the time occupied being three minutes.

**Working Coal.**—H. Gutmann \* discusses the mining of somewhat thin flat-lying seams of coal. He describes and illustrates a method, and enumerates a number of advantages which he considers it to possess.

O. Curtz † describes some typical examples of pillar-and-stall and long-wall workings in England and Germany.

A description has appeared, ‡ of a method of filling worked seams with mining waste at Arnao Colliery (Asturias), Spain, rendered necessary in working a seam with a thin cover rock under the sea, the circumstances being complicated by the strong tendency of the coal to ignite spontaneously.

F. G. Meachem § gives an account of several eruptions or earth explosions, locally called bumps, at Hamstead Colliery, Staffordshire. Roads were driven at the bottom, top, and in the middle of the seam, which is here 24 feet thick, and lies at a depth of 1950 to 2100 feet; but bumps occurred in all positions, whether the work advanced quickly or slowly, and in spite of careful timbering and advance bore-holes. In the discussion several explanations were offered, such as pressure and tension in the strata and gas pressure. Outbursts in other localities were also mentioned.

\* *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xlv. pp. 59–63, with six illustrations.

† *Jernkontorets Annaler*, vol. li. pp. 158–201.

‡ *Zeitschrift für das Berg-, Hütten- und Salinenwesen im preussischen Staate*, vol. xliv. pp. 395–401.

§ *Transactions of the Federated Institution of Mining Engineers*, vol. xii. pp. 613–618, with one plate; *Transactions of the Manchester Geological Society*, vol. xxv. pp. 83–94, with two plates.

**Pumping Appliances.**—W. Galloway \* describes the principal pumping engine at Llanbradach Colliery, and briefly mentions the methods of dealing with the water during the sinking of the pits. The pump is a triple expansion direct-acting Worthington engine, with steam-cylinders 13, 18½, and 30 inches in diameter, and the plungers are 9½ inches in diameter. The common stroke is 2½ feet. The normal speed is 140 feet per minute, and the pump is capable of raising 750 gallons per minute to a height of 800 feet with an effective steam-pressure of 120 lbs.

At a shaft near Aschersleben, a pumping appliance on the Kaselowsky system is in use for raising water from a depth of 1050 feet.† The source of power is a pump worked by water under great pressure. Two hundred and twenty-one atmospheres pressure is used in this case, a differential pressure pump at the surface coupled direct to a 200 horse-power steam-engine at the surface, being used as the prime source of power. Only a small quantity of water is necessary. A pump on this system is used at the Pluto Colliery in the Gelsenkirchen mining district, which raises 88·3 cubic feet of water per minute from a depth of about 1660 feet. In this case the water, mixed with vaselin, is subjected to a pressure of 200 atmospheres, and then passed to an accumulator, whence it passes through a pipe having a wall thickness of 0·39 inch and 2·56 inches in internal diameter to a pump placed at a depth down the shaft of 1660 feet. A description of the plant is given.

C. Behr ‡ deals generally with pumping appliances and mentions the arrangement, thickness, and protection of the pipes, air chambers, relief valves, pump valves, &c.

N. Trestrail § discusses the duty of Cornish pumping-engines past and present, and compares them with other engines. The variations in the duty obtained are traced, and particular mention is made of instances in which high duty has been obtained. It is contended that the superiority of other pumping-engines is not established.

W. Howe || describes an interesting application of steam which has recently been twice made at the Clay Cross Collieries for the purpose of lifting a rising main, 720 feet long and weighing approximately 30 tons.

\* *Transactions of the Federated Institution of Mining Engineers*, vol. xii. pp. 294-302, with two plates.

† *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xliv. p. 573.

‡ *Canadian Mining Review*, vol. xvi. No. I. pp. 21-23, &c.

§ *Transactions of the Federated Institution of Mining Engineers*, vol. xii. pp. 548-562.

|| *Ibid.*, pp. 105-106, with plate.

After steam had been turned into the pipes and expanded them, they were firmly clamped to buntons 180 feet above the bottom. On cooling and contracting, a new pipe was introduced, and then steam turned on again, so that the pipe expanded to allow the joint to be completed. The whole operation took four hours.

According to W. Galloway,\* pumps, as a rule, are most economical, but in circumstances certain recourse must be had to water-boxes. Such occasions sometimes occur during sinking or sudden flooding, especially when the flow of water is not permanent, so that pumps, if installed, would lie idle afterwards. A small constant flow of water is also most effectively dealt with in this way. When sinking at Llanbradach Colliery, in Wales, where the author's other appliances for walling and guiding were so successfully used, the water-tub was found to be of the greatest service. A bore-hole conveyed the water from the sinking down to headings below. At a depth of 558 feet, water to the amount of 55,000 gallons had to be dealt with, so two water-tanks were made, intended to work between two wire-rope guides, and the conditions which they were required to fulfil were as follow :—

- (1.) To have a capacity of 1000 gallons.
- (2.) To fill and empty without having any tendency to push the guide-ropes out of their normal position.
- (3.) To fill and empty in the shortest possible time.
- (4.) To be emptied automatically.
- (5.) To deliver the water as nearly horizontally as possible, and with such velocity as to carry it clear of the opening through which the bucket was drawn on reaching the surface.

By having large valves worked by levers struck by stops at the top of the shafts, these requirements were accomplished, and the minimum quantity of water raised was 70,000 gallons per hour, and the maximum 110,000 gallons per hour. The minimum quantity raised by the two tanks in No. 1 pit was 1000 gallons per minute at the commencement, before the enginemen had become familiar with the work, and this gradually increased up to 94,000 gallons, or 94 tanks per hour. The quantity of small coal consumed by all the engines amounted as nearly as may be to 10 pounds per horse-power of actual work done in raising water per hour. The cost per ton of water raised 600 feet amounted to 0·347d. per ton approximately. A locked coil wire rope of 1½ inch diameter, weighing 23 lbs. per fathom and 1965 feet long, was used

\* *Transactions of the Federated Institution of Mining Engineers*, vol. xiii. pp. 74-90.

throughout without appreciable wear. Some little time was lost in lengthening the rope as the water sank in the shaft, but this might be diminished in future work by better arrangements.

E. Dawson \* mentions the principal exhibits of machinery at the Cardiff Exhibition in 1896, and describes some of them. Amongst these are Riedler pumps and compressors with positively-worked valves, oil-engines, electric light machinery, fans, winding-engines, and pumps and engines generally.

**The Ventilation of Collieries.**—J. Mayer † discusses the question of the ventilation of collieries, pointing out the necessity of a good ventilation at all the working faces, and considering the best methods of effecting this. Separate systems of ventilation on a large scale should be used for different parts of the mine, it is true, to prevent widespread accidents, but the use of a great number of small secondary systems of ventilation he considers objectionable.

W. Clifford ‡ describes furnace and fan ventilation, giving instances of English practice where large quantities are circulated through deep collieries. The Guibal and Capell fans are then specially considered, and the results obtained with them at various mines are given, together with the factors which control the choice of a fan.

T. A. Southern,§ in a recently published lecture, discusses at some length the water-gauge in a fan, and in various parts of the mine, the ventilation of rise and dip workings, &c.

An account is published by Von Ihering || of experiments made by him with the Mortier fan. With a diameter of fan of 6 feet 10 inches, and a breadth of 4 feet 7 inches, the fan yielded 2920 cubic metres of air at 348 revolutions per minute, with a depression of 6·14 inches of mercury. G. Herbst ¶ also discusses the theory of the Mortier fan, and deals with the various types of fans.\*\*

G. H. Hollingworth †† describes some of the means devised for the covering of up-cast pits, where used for winding purposes, with the

\* *Proceedings of the South Wales Institute of Engineers*, vol. xx. pp. 102-121.

† *Oesterreichische Zeitschrift für Berg- und Hüttewesen*, vol. xliv. pp. 577-581.

‡ Paper read before the Ohio Institute of Mining Engineers, January 21, 1897, through the *American Manufacturer*, vol. ix. pp. 228, 284, 301.

§ Lecture delivered at University College, Nottingham, February 13, 1897, through the *Iron and Coal Trades Review*, vol. liv. pp. 433, 475, 506, &c., and other papers.

|| *Oesterreichische Zeitschrift für Berg- und Hüttewesen*, vol. xliv. p. 688.

¶ *Glückauf*, vol. xxxii. p. 729.

\*\* *Bergbau*, vol. x. No. 6, p. 9.

†† *Practical Engineer*, vol. xiv. pp. 484-486.

object of so closing the top as to prevent loss or leakage of air without materially interfering with the banking operations.

A description has appeared of W. Smit's electrically-driven fan,\* and J. T. Beard † discusses the equivalent orifice method for determining the efficiency of fans.

**Safety-Lamps.** — J. Gregory ‡ describes a modification of safety-lamps for ensuring that the gauze is inserted, and thus avoiding the danger of omitting it in bonneted lamps where it cannot be seen. For this purpose the gauge is attached to a metal ring with two screw-threads on it, and serving as a junction piece for the upper and lower parts of the lamp.

A few years before the invention of the first safety-catch in 1846, Müseler of Liége invented the safety-lamp that bears his name. One of the first collieries at which it was adopted was the Six Bonniers at Seraing, of which C. Büttgenbach, the inventor of the safety-catch, was manager. §

V. Waltl || observes that one of the difficulties connected with the use of portable electric lamps in collieries lies in the fact that they do not admit of the detection of gas without the aid of a subsidiary appliance. Electric lamps of this kind possess either primary or secondary batteries. In both systems more or less acid vapours are always evolved, which have a tendency to attack the less protected portions of the lamps, and there are other difficulties connected with the constant use of such lamps, to which the author refers. For charging the lamps at present in use, a current of one ampere, acting during a period of from eight to ten hours, is necessary. It is better, however, to use a weaker current, and to allow it to act during a longer time, rather than to employ a stronger current and a shorter period. When charging the lamps an ampere-meter ought always to be used. A secondary battery of lead plates, with sulphuric acid as the exciting agent, gives a current from 2 volts downwards, and the charging current should possess an intensity of from  $10\frac{1}{2}$  to 12 volts. A dynamo should be employed in charging such batteries. The author then proceeds to describe various systems of portable electric lamps, including those of Swan, Schanschleif, Pitkin,

\* *Engineering*, vol. lxii. p. 459.

† *Colliery Engineer*, vol. xvii. p. 78.

‡ *Transactions of the Federated Institution of Mining Engineers*, vol. xii. pp. 588-590, with illustrations.

§ *Revue Universelle des Mines*, vol. xxxvi. p. 124.

|| *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xliv. pp. 37-38.

Walker, the Electric Syndicate, and Vaughton. He points out that the prices of electric lamps, as shown by those he quotes, are relatively considerably higher than those of the ordinary safety-lamps as usually employed in collieries, and he thinks that this may be the cause why the use of electric lamps in collieries has not made greater progress.

**Fire-Damp.**—J. Mayer \* discusses the work on fire-damp published by Behrens,† who deals largely with the methods in use at the Hibernia Colliery for diminishing danger from this source. This colliery has a surface area of about 1300 by 1500 yards. It is provided with three shafts close together, two of which serve as intakes, and one for the escaping air current. The conditions being favourable, the distance an air current has to pass through does not exceed 2500 yards. The quantity of air passed through the colliery per minute is as much as 6000 cubic metres, or 10 cubic metres (353·2 cubic feet) per workman employed underground. This causes the temperature in the colliery to be quite low, notwithstanding the depths of the workings are from 1410 feet to 2000 feet. It does not exceed 23° C. anywhere, and varies usually between 18° and 22°. The system of ventilation at this mine is described in detail. The colliery is a very dry one, and a good deal of coal-dust is the result of the powerful air current passed through the mine. To avoid this a system of pipes 45,820 metres in length has been laid down, and water under high pressure is passed through them and distributed freely by hydrants provided with sprinklers throughout the workings. The causes which lead to the evolution of gas are dealt with, and the results of a large number of experiments connected with this subject are given. Forty-two holes were driven to ascertain the pressure of the gas in the coal at the Hibernia Colliery, and 598 determinations of this were made. The highest pressure tabulated is 5·20 atmospheres, but in one case a pressure of 14·6 atmospheres was observed. It was found that both the pressure of the gas in the coal and the quantity of it escaping diminished with the length of time the face of the coal had been exposed. Behrens thinks that the pressure of 42·5 atmospheres observed at a Belgian colliery probably represents the maximum pressure for gas in coal. The quantity of gas that escapes from coal is less due to this pressure than to the degree of porosity of the coal. Deductions drawn by Behrens as to the question of the pressure of gas in coal and the quan-

\* *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xlv. pp. 43-46, 63-67, and 74-79.

† Eeson, 1896, with nineteen plates and numerous illustrations in the text. Price 6s.

tity escaping are criticised adversely by Mayer. Another point dealt with by the former writer relates to observations made to ascertain how far the quantity of gas that escapes from coal is dependent on the atmospheric pressure. While these showed that with a low barometer more gas escaped, they did not show that the variations in the quantity escaping coincide with the variations in the height of the barometer. With reference to the large quantity of gas that escapes from a colliery, it is calculated that that escaping during the year from the Hibernia Colliery is of a value as high as about £150,000. In Ostrau, too, it was shown that the value of this lost gas might exceed the value of the coal actually won.

A. Fillunger \* discusses breathing appliances for miners, and pays particular attention to the Walcher-Gärtner appliance. The various systems of breathing appliances are discussed separately, and the names of the various inventions coming under each head are given. The Walcher-Gärtner is an oxygen-supplying breathing apparatus. Of this and other similar appliances the author gives illustrations, and details of the use in practice of the Walcher-Gärtner apparatus are also supplied.

Shaw's gas-tester is described in detail by A. P. Morewood † and by C. Fergie.‡

R. Jeller § describes an apparatus for determining gaseous constituents present in small quantities, especially marsh-gas and carbonic anhydride, in colliery gas.

**Colliery Explosions.**—J. S. Haldane || finds that most of the deaths in colliery explosions are due to poisoning by carbonic oxide in the after-damp, and the proportion of those otherwise killed by burns or other injury is 23 to 31·6 per cent. in three explosions last year. The men poisoned by carbonic acid could in many cases be resuscitated by using oxygen. In many cases the air after an explosion contains sufficient oxygen to support life. Various suggestions are then made as to the possibility of escape and of minimising the effects of an explosion.

H. Hall ¶ tabulates the causes of explosions over the last twenty years,

\* *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xliv. pp. 581-585, and 591-598, with twelve illustrations.

† *Proceedings of the South Wales Institute of Engineers*, vol. xx. pp. 46-63, with plate.

‡ *Canadian Mining Review*, vol. xvi. No. I. pp. 17-18.

§ *Zeitschrift für Angewandte Chemie*, 1896, p. 692.

|| *Transactions of the Federated Institution of Mining Engineers*, vol. xi. pp. 502-514; vol. xii. pp. 60-73.

¶ *Ibid.*, vol. xi. pp. 526-535.

and very strongly urges that the use of open lights and blasting-powder should be discontinued.

W. J. Orsman \* also gives some notes on the explosion of coal-dust. The explosion which occurred on December 18, 1896, at the Szécsen Colliery, Reschitz, resulted in the deaths of eighty of the 110 workmen in the mine. It was probably due to a faulty safety-lamp. The lamps used were the Wolf benzene lamps with ignition strips. The flame of the explosion was some 1000 yards in length, but the mine itself did not take fire. This explosion is of interest not only on account of the length of the flame, but from the fact that for 200 yards of its course the flame passed through a wet part of the shaft.†

**Coal-Dust in Mines.**—The danger that exists owing to the presence of coal-dust in collieries can be met in various ways.‡ All depends on some method of keeping the dust damp. These include the use of hygroscopic salts, steam, moistened surfaces, movable water-tanks or water-pipes laid down in the mine. Ordinary sea-salt seems useless, but calcium chloride seems to give good results. The use of steam is not, as a rule, possible, and the injection of steam into the down-take shaft shows no results at a distance of 400 yards from the bottom of the shaft. Letting the air current pass over moistened surfaces seems to be of advantage. The air becomes damper, and does not dry the dust so much, the dust, too, settling more readily. The ventilation may in this way be improved. Of the various methods for sprinkling water in the pit, movable water-tanks are most used. These are of various kinds. Those used for wetting the sides of the roads, &c., are of two kinds, one of which has a mechanical appliance for sprinkling the water, while in the other compressed air is used. The pipe system is also described.

An instance of the spontaneous ignition of coal-dust has recently been given by Osterkamp as having occurred at the surface works of the Maybach Colliery in the Saar district. The dust from the screens had settled on the walls, &c., and in contact with corrugated plates exposed to the sun, and appeared to have been burning for some time.

D. M. Stuart § again gives his theory of the phenomena of colliery explosions, and discusses the evidence previously adduced in his books

\* *Transactions of the Federated Institution of Mining Engineers*, vol. xi. pp. 536-539.

† *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xlvi. p. 37.

‡ *Ibid.*, vol. xlvi. pp. 104-106.

§ *Transactions of the Federated Institution of Mining Engineers*, vol. xii. pp. 371-407; *Nature*, vol. lv. p. 597.

on the subject. The matter was criticised at length and somewhat severely.

**Mine Fires in Ohio.**—In 1884 several of the slopes and tipples about the mines at New Straitsville, Perry County, Ohio, were set on fire, which spread to the workings, and has been burning ever since. Efforts are being made to extinguish or isolate the fire. The seam is above water-level, and is worked entirely by slopes and drifts. It averages 6 to 8 feet in thickness, and is covered by 4 feet of soft slate and 20 feet of sand rock. The surface is extensively broken.\*

**The History of Coal-Mining.**—R. L. Galloway † has continued to publish further instalments of his comprehensive history of the British coal trade.

J. Raubert ‡ states that 700 years ago, in 1197, a Liége blacksmith found, near Publémont, a black earth which he used as fuel; but, as records Jean de Preis, every one helped himself to it for two or three years, until the owners interposed and worked the coal for sale. The smith who discovered the new fuel was called Hullioz, whence the name of *houille* for coal, and *houillère* for colliery. It is therefore to Belgium that belongs the honour of discovering the fuel universally employed by modern industry; and it is certain that coal was first used in that country, authentic documents proving that collieries were being actively worked in the principality of Liége during 1228, and in Hainaut the following year. In France, however, there is no mention of coal being worked before the fourteenth century, the colliery of Roche-la-Molière having been opened about 1320, while in the fifteenth century a few deposits were discovered in the Charolais by men employed by the Dukes of Burgundy. Belgians also had the largest share in turning to account the rich northern coalfield, the celebrated Anzin seam having been discovered in 1734 by Pierre Mathieu, of Lodelinsart, near Charleroi, while the first edict mentioning coal in France dates from the year 1601.

Among the other countries of Europe, Austria and Bohemia neglected the mineral fuel contained in their mountains until the last century; but on the advice of Prince Charles of Lorraine, Governor-General of the Low Countries for the Empress Marie Thérèse, Belgian engineers

\* *Engineering and Mining Journal*, vol. lxii. p. 582.

† *Colliery Guardian*, vol. lxxii. pp. 867, 918, 961, 1009, 1059, 1107, 1153, 1201; vol. lxxiii. pp. 15, 63, 109, 158, 249, 297, 347, 393, 437, 551, 598, 625, 671.

‡ *Echo des Mines*, vol. xxiii. p. 1811.

were called to Vienna in 1757 for conducting the first explorations of any consequence in the country. Kircher, in his *Mundus Subterraneus*, records that in Hungary during his time (1665) no account was taken of coal, because "its force was so vehement that it consumed iron, and indeed all the metals." In North Germany, on the contrary, it appears that the working of various coal deposits was begun about the year 1500; but only the collieries of Saxony, Silesia, and the Ruhr district attained any importance before the present century.

J. Barrowman\* deals shortly with the past and present working of coal in Scotland, and briefly describes modern improvements in methods of working.

**Mine-Surveying.**—R. F. Percy † describes the determination of, and the use of, the magnetic meridian in mine-surveying.

Bennett H. Brough ‡ describes the methods of conducting levelling operations in mines.

**Collieries in Great Britain.**—Detailed descriptions have been published in the *Colliery Guardian* of a number of British collieries. The list includes Preston Grange Colliery (vol. lxxii. p. 822), Newbattle Colliery (p. 882), Elphinstone Colliery (p. 915), Whitehill Colliery (p. 1013), Loanhead Colliery (p. 1061), and the oil shale works at Clippens (p. 1157), in the Lothian coalfield.

The following collieries in the Lanarkshire coalfield are also described : Milnwood Colliery (vol. lxxii. p. 1110), Nielstrand (vol. lxxiii. p. 64), Eddlewood (p. 112), Auchinraith (p. 157), Bardykes (p. 205), Udston (p. 252), Quarter (p. 299), Gateside (p. 348), Gilbertfield (p. 394), Whitehill and Greenfield (p. 439), Dechmont (p. 487), Newton (p. 535), Foxley (p. 585), Swinhill (p. 625), Bogleshole (p. 671).

The collieries in the Fifeshire coalfield comprise : Kelty (vol. lxxii. p. 721), Lochgelly (p. 774), Halbeath and Kingseat (p. 963), Blairhall (p. 1202), Balgonie (vol. lxxiii. p. 18).

Descriptions have also appeared of Ashington Colliery, Northumberland (vol. lxxii. p. 962).

In the *Journal of the British Society of Mining Students*, J. R. Gilchrist describes in detail the Chopwell Colliery, Durham. This new

\* *Iron and Coal Trades Review*, vol. liv. pp. 164-165.

† *Transactions of the Federated Institution of Mining Engineers*, vol. xii. pp. 581-584.

‡ *Colliery Guardian*, vol. lxxiii. p. 537; *Mining Journal*, vol. lxvii. p. 354; *Iron and Steel Trades Journal*, vol. ix. p. 365; *Iron and Coal Trades Review*, vol. liv. p. 485.

winning has been formed to work the coal west of what is known as the Tantobie Dyke, which runs north and south, and forms a natural boundary between this colliery and Garesfield Colliery, both the property of the Consett Iron Company, Limited. The dyke has a dip to the west of from 30 to 40 fathoms. The northern boundary is the well-known 90-fathom dyke, which runs from the east to the west coast, and the course of which, through the Company's royalties, is practically east and west. As the royalty is over 2000 acres in extent, and the life of the colliery a long one, the work is being carried out with this in view, and the buildings and plant are of a substantial character.

**Continental Collieries.**—E. R. Schoch \* gives a short description of a typical colliery in Saxony, the one selected belonging to the Zwickau-Oberhohndorfer Steinkohlen Verein, which owns 640 acres and a coal-washing plant. This area is traversed by a fault, raising the coal on the south about 160 yards. There are three shafts, one of which is divided into two, and is about 430 yards deep. It will, however, be sunk deeper, as there are seven workable seams with a thickness of 27 yards. Endless-rope haulage and compressed air hoists are in use underground. The pillar-and-stall system is used, and blasting is practically prohibited. Wolf benzine safety-lamps with self-lighting arrangements and magnetic locks are employed. About 1200 men are employed, and the production ranges from 22,000 to 31,000 tons monthly, according to the season of the year.

In his official report, M. Tauzin,† the Government inspector, deals with the production, methods of working, wages, ventilation, explosives, pumping, &c., in the Loire district.

E. Duporcq ‡ gives economical and technical observations and a description of the colliery working of the Pas de Calais coalfield.

**The Drummond Colliery.**—C. Fergie § has published an illustrated description of the Drummond Colliery, Westville, Pictou County, Nova Scotia. The paper is illustrated by drawings and photographs of the engine-house and surface works, of the screening plant, of the reserve fan, of the new fan building, of the coke-ovens, and of the shipping pier at Granton. The coal area covers  $2\frac{3}{4}$  square miles, and four workable seams have been proved. The main seam is worked by slopes 4658

\* *Engineering and Mining Journal*, vol. Ixii. pp. 607-608.

† *Colliery Guardian*, vol. lxxiii. p. 368.

‡ *Ibid.*, vol. lxxii. p. 1028.

§ *Colliery Engineer*, vol. xvii. pp. 329-335.

feet in length, the pillar-and-stall system being employed. There are twenty beehive coke-ovens, each charged with 5 tons of washed coal. The yield of coke is 3 tons 4 cwt.

**Coal-Mining in Illinois.**—In the Grundy County fields, forming the northern extremity of the Illinois coalfield, the No. 2 seam lies at an average depth of 100 feet, and does not vary much from 3 feet in thickness. All the coal is worked long-wall, and there are ten large collieries within 18 square miles. A typical colliery is the Braceville No. 4 mine. Here the shaft is 143 feet deep, with two hoisting compartments 5 by 5 feet, and one air compartment 2 by 5 feet. A second shaft for the men is 5 feet square. Sinking is difficult, owing to quicksands 12 to 20 feet below the surface. There are four pumps at the bottom of the shaft, one being held in reserve, one for lifting the water to the surface, and the others draining the mine through a system of branching pipes led to small sumps at the face, where they are furnished with ball-cocks which close automatically when the water is exhausted.

Instead of ordinary cages, the hoisting shaft has two V-shaped buckets 5 feet square at top and 5 feet deep, holding 2700 lbs. of coal. The tubs, as they arrive at the pit bottom, are emptied into these buckets, and these latter are tipped by the engineman when they reach the surface. The daily out-turn of coal is 1474 tons of coal in ten hours, in addition to 500 tons of fireclay. The working face is elliptical, with the shaft at the centre. Cross roads are driven every 300 feet at an angle of 60°, while the main roads and the working roads are 50 feet apart. Three men work in each face and hole under 5 to 6 feet; the coal falls without much powder. No gas is met with.\*

The Virden Colliery, 60 miles north-east of St. Louis, in Illinois, has a shaft 8 by 16 feet and 320 feet deep. An illustration is given of the surface buildings,† showing the head gear covered in. The shaking screens are placed in a building separated from the head gear by a small space to avoid vibration. Self-tipping cages are used, and these shoot the coal out of the tubs into a screen, from which the small goes to a pair of shaking screens, of which one is mounted on wheels. Double direct acting winding-engines, 20 by 32-inch cylinders, are supplied with steam by four 5 by 16 feet tubular boilers. The seam is 7½ to 8 feet in thickness, and the coal is blasted from the solid. Cross entries 8 feet wide are driven every 400 feet from the main road, which is 12 feet

\* *Engineering and Mining Journal*, vol. lxii. pp. 487-488.

† *Ibid.*, vol. lxii. p. 608.

wide. Rooms are turned off 8 feet wide, opening out to 25 feet, and are driven 170 to 180 feet long. All the coal is raised. The hoisting-shaft is used as the upcast, and the escape shaft is 300 feet distant. The men employed number 260, and the daily out-turn is given as 1800 tons.

Eight miles west of Danville, Vermilion County, Illinois, is a natural depression 80 feet below the surrounding country, and having an area of about 1000 acres, underlain at a depth of 9 to 30 feet by a 6-foot seam of coal. The overburden of clay and gravel, and in some cases soapstone, is stripped, and then vertical holes are bored into the coal. A small charge of dynamite is first exploded in them, and then the coal is broken up by powder. To remove the cover, shovels carried by a boom of piping, from  $2\frac{1}{2}$  to 6 inches diameter in the largest machines, are worked from a travelling derrick some 60 feet high. Soapstone when present is blasted. Three machines are at work night and day, and the out-turn of coal is 1000 tons daily. The coal is soft, but it makes a very fair steam-coal.\* An illustration of the excavating machine is also given.†

An illustrated description is given ‡ of a colliery near Staunton, Illinois, which produces 1000 tons of lump coal and 400 tons of small coal daily. Four hundred men are employed. The shaft is 329 feet deep, and the seam is  $6\frac{1}{2}$  feet in thickness. Coal is treated by shaking screens, and hand-picking is employed. Underground endless-rope haulage is at work. Fan ventilation is employed. Pillar-and-stall workings are followed, cross entries are driven off every 400 feet, and the stalls are turned off from each entry to meet at the centre, being made 40 feet wide and 60 feet apart. About a third of the coal is left permanently as pillars, and no timbering is necessary. Nineteen Harrison and three improved Yoch machines are at work for undercutting in the coal itself, 5 feet wide and 5 feet deep at each setting. From 200 to 250 square feet are cut in each shift, and each machine produces about 100 tons of coal in twenty-four hours.

**Mining in Ohio.**—At the Congo Colliery, in Ohio, a seam 13 feet thick, lying at an average depth of 33 feet, is worked. Eight Jeffrey chain-cutting machines are used in the mine, and are driven by electricity, which is conveyed by cables passing from the surface through a 10-inch borehole. Horse haulage and  $2\frac{1}{2}$  ton trucks are employed. The seam is worked pillar-and-stall by the double entry system. The top  $4\frac{1}{2}$  feet of coal is left as the roof until the pillars are drawn. Roads are

\* *Engineering and Mining Journal*, vol. lxii. p. 587.

† *Ibid.*, vol. lxiii. p. 165.

‡ *Ibid.*, pp. 139-141.

driven 12 feet wide, and the stalls are driven 30 feet wide every 50 feet for a distance of 400 feet.\*

**Economics of Coal-Mining.**—H. Louis† discusses the economics of coal-mining, and gives in graphic form the percentage production of different countries of the world from 1840 to the present time, showing a decrease from 75 to 34 per cent. of the total for this country. In connection with Rainton Colliery, recently closed down, the following figures are given for the cost per ton, as shown from the cost-sheets on a production of 163,074 tons of vendable coal out of the 202,993 tons raised :—Wages and house-rents, 6s. 10·86d. ; supplies and horses, 1s. 1·54d. ; royalties, way-leaves, and rent, 5·12d. ; rates, salaries, office, and sundries, 5·99d. ; total, 8s. 11·51d. The cost of labour is thus 77 per cent. of the total. It is then shown that the production of coal per workman in this country is less than in the United States, and it is suggested that certain provisions of the Coal Mines Regulation Act might be modified. Restriction in output is condemned.

W. Blakemore ‡ discusses the question whether there is an economic limit to the output of a coal-mine. After referring to the numerous pits placed close together, with very small individual outputs, mention is made of the outputs of 1000 tons daily, which date from 1870, now increased to 2000 tons in some Lancashire and Welsh pits, and over 3000 tons in Ohio, Pennsylvania, and Wyoming. The thickness of the seam is one controlling factor, and apparently at present no mine winds as much as 2000 tons daily from a single shaft from a thinner seam than 5 feet. The size of the tub must be increased, as at Nottingham Colliery, Wyoming, where a three-ton tub is used, and an output of 3000 tons obtained from a thick seam where the haulage almost resembles that on the surface. A good roof and floor are very necessary, and faults must be absent. The author is inclined to limit the possible number of single hoists in one shaft to 1000, or perhaps to 1200 single hoists per day. The Rhondda Colliery, South Wales, is taken as an example of a colliery raising 2000 tons daily from a 5-foot seam, with excellent underground haulage and tubs holding about a ton. These outputs may then be taken as the limit for successful working.

R. Danilof § states that a system has been introduced at the Heinrichsglück Colliery, Peterswald, for the control of the numbers and

\* *Engineering and Mining Journal*, vol. lxiii. p. 259.

† *Iron and Coal Trades Review*, vol. liv. pp. 178-180.

‡ *Canadian Mining Review*, vol. xvi. No. I. pp. 16-17.

§ *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xlv. pp. 172-173.

times of the workmen going underground and returning to surface, which consists in the use of a series of marked tags. Each workman has a number allotted him, which corresponds with his lamp number. He is known by this number in the works book. When he reaches the shaft-house to go to work, he receives there his numbered tag, and goes underground in the order he arrives. At the bottom of the shaft he gives up his numbered tag. This has a hole through it, and when given up is strung on a stick. At the end of the shift this stick is reversed, and each man comes forward to claim his tag and to go to surface in the order in which the tags stand. Should any of these be unclaimed, it is seen at once that the men to whom they belong must be still underground. When it is a question of dealing with large numbers of workmen, these might be easily overlooked. On reaching the surface the men have to give up their tags again. A great saving in time is effected in this way, a quarter of an hour sufficing to clear off 250 men. If a man reports himself, but states he cannot go underground, his tag is covered with another marked with the letter U, which means, "The man did not go to work, but notified this." Covering the tag with another marked K, means that the man is ill; another tag labelled O means that the man has not gone to work, and has not reported himself. The workmen have now grown accustomed to leave their working places, when going to the surface, at such a time as to arrive at the shaft in about their proper order for going up.

D. T. Day\* discusses the prospective resumption of mining activity in the United States in 1897. Industrial expansion must be anticipated by a correspondingly increased supply of the crude minerals necessarily involved, and now the United States not only supplies nearly all her own wants in this respect, but is besides the greatest mineral producer in the world—furnishing nearly two-thirds of the world's petroleum, more than half of all its copper, one-third of the pig iron and coal, and nearly one-fourth of the gold, iron ore, and zinc. Greater values are exported than imported. Three hundred industrial plants were started between Election day and November 10, and the prospective demand for raw material raised the freights in the Lake Superior district in spite of large stocks at Cleveland and other ports. It is expected that the make of pig iron may even exceed that of 1895. The idle coal-mines in the United States may be estimated at 250, with a possible output of three million tons of coal; and if all the mines working half time are included, an increase of twenty-five million tons could be attained.

\* *Engineering Magazine*, vol. xii. pp. 621-629.

with practically the present plants. The production of gas from culm at the mines and the export of coal offer a vast future, whilst oil, in spite of the steady demand for illuminating purposes, may advance greatly, owing, *inter alia*, to the decrease in the natural gas supply. Cheap methods of mining and handling ore in the Lake Superior district and other details are also briefly discussed.

In the whole kingdom of the Netherlands only two collieries are at work.\* These are both close to the Prussian frontier, and about five miles north of Aix-la-Chapelle. The smaller of the two belongs to an adjacent Prussian colliery company, with one of whose collieries in Prussia it is in direct underground connection. The second belongs to the State. The two collieries are in full work, and give employment to 600 workpeople. The seams are much folded, but not broken at the folds. Some 40 deep boreholes have shown that an extensive coalfield exists in this part of Holland, covering about as much as 50,000 acres. In Holland the Code of Napoleon (1800) is still in force, and forms the mining laws. But little work has yet been attempted in connection with the coal deposits. It has now been shown that in the adjacent Wurm coalfield coal-mining was practised in the year 1113, or seventy years before coal was mined for in the Liége field, though text-books always state this latter as the first known mining for coal in Europe. The Wurm coalfield now gives employment to nearly 8000 miners.

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#### IX.—COAL-WASHING.

**Screening and Tipping Coal.**—J. Rigg † gives an account of the various forms of screening and tipping machinery employed in recent practice. Greater importance is now placed upon the preservation of coal from damage in loading, screening, and in transit than formerly, on account of the keener competition in the supply of coal for domestic purposes. The leading types of trams and corves, as influencing the methods of tipping, are illustrated and described. It is pointed out that end-doors caused the weakened sides of trams so constructed to involve a permanent and continual expense for repairs, and, having regard to all questions to be considered, including accidents and occasional collisions, the “box” tram, with timber sides and steel or iron floors, is

\* *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xliv. pp. 144–146.

† *Minutes of Proceedings of the Institution of Civil Engineers*, vol. cxxvii. pp. 163–175.

advocated. Illustrations are shown of the various methods of tipping, also the method of delivering from open-ended corves without the adoption of a tip; and various forms of tipplers, oscillating as well as revolving both forwards and backwards, with and without the assistance or control of counterbalance weights and brakes, are described. Diagrams are likewise given to prove that the fall of coal from side-tipped corves is greater than that from corves tipped endwise, and that the arrangements often made by colliery proprietors, at inconvenience and expense, to bring on the coal from the former direction are consequently not productive of the economy believed to result. It is contended that the tipping of open-ended trams caused the largest and most valuable coal, forming the top of the load, to leave first and sustain severe shock and breakage on the screen, and that it consequently is not protected by the lower coal. The author then describes his form of tippler, which is counterbalanced and under control of a brake, and the coal is received upon a plate at right angles to the floor of the corve or tub and checked by a light balanced door. The fall, common in various degrees to all the other forms of tips, is thus entirely prevented. This tipping machine is also used for the loading of coal from end-door railway waggons.

For screening and separating coal, the revolving or barrel screen is so destructive to the coal as to be quite unsuitable to that intended for domestic use. In a less degree vibrating riddles cause similar injury, and involve the expense of the power needful to drive them. An illustration is also given of what is considered one of the best forms of picking-belt, with screens, and loaded by revolving side-tips; and the author contends that, inasmuch as the travel of this belt is definite, and the quality of the coal, as regarded need for picking, varies widely, a much larger number of pickers must be employed to secure the best results than is needful for the average work, and consequently unnecessary expense is incurred.

The sections of the leading types of screen-bars are examined, and the objections to those with round and particularly diamond-shaped heads pointed out; it is shown that by setting light flat-topped steel bars in ranges of short lengths, alternating bars and spaces in each range, the slack is effectually entrapped in the upper end of the screen-hopper without any other aid than the force of gravity. The pitch between these bars can also readily be changed to suit the varying demands in different seasons. Descriptions are also given of fixed screens, suitable for special purposes, and of a curved balance screen worked under the

control of a brake, and, for loads of 16 cwts. and upwards, under that of a cataract cylinder. The coal distributes itself over the lower end of this screen, and can be readily sorted. Whether much or little labour is involved in this process, the number of pickers is small, because the operator has complete control over it, and on the release of the brake or cataract its weight causes it to descend gently to the angle of delivery, an automatic latch preventing the actual passage of the coal into the truck until the screen attains the correct angle of delivery to secure the minimum of fall at this point. The most effectual and economical methods of tipping and screening or separating coal are those employing the force of gravity only.

Four full pages of dimensioned drawings are published\* of the details of the coal-conveying, screening, and sorting plant at the Aberaman Colliery of the Powell Duffryn Coal Company. The loaded tubs are taken by a creeper chain up an incline to the tipplers, which are driven by power automatically applied. The three tipplers will each empty six tubs of 35 cwt. each per minute. The large coal passes down over fixed screens on to jiggling screens, and then into "billy-fair-play boxes," where it is weighed. The small coal passes through the screens into a hopper with a trap-door at the bottom, and these trap-doors are connected to a weighing device so as to weigh the small coal from each tub. The fixed screens have a slope of 1 in 2, and are 15½ feet long by 6 feet wide, with screen bars 12 feet long, tapering from  $\frac{3}{4}$  to  $\frac{1}{2}$  inch. The jiggers are 7 feet long by 7 feet wide at the top, and tapering to 4½ feet at the lower end. Each jigger is driven by an excentric with a stroke of 8 inches. These jiggers deliver the coal evenly over three picking bands each 52 feet long, of which 37 feet runs on fixed framework, the remaining 15 feet being free to swivel up and down so as to adjust the height of fall into the railway trucks.

J. Hastie † describes the coal-cleaning plant at Whistleberry Colliery, Hamilton. Both shafts are used for winding, and the tubs run over two weighing machines to three automatic tipplers which empty the coal on to distributing jiggers from which it passes to screening jiggers. Large coal goes on to three picking bands of the bar-grating type, which have radially movable ends to adjust the height of fall into the waggons. Dross coal from the jiggers and from the large coal belts are conveyed by a transverse conveyor with scrapers to two vibrating nut screens

\* *Engineer*, vol. lxxii. pp. 409, 410, 418, 461, 470.

† *Transactions of the Federated Institution of Mining Engineers*, vol. xii. pp. 622-631, with two plates.

working in opposite directions, and making four sizes—gum, singles, doubles, and trebles. The three latter are picked on belts. The nut bands are inclined downwards at the delivery end to diminish breakage consequent on the fall. A conveyor runs transversely below the picking belts and receives rubbish through holes in the floor. Twelve hundred tons daily can be treated.

At the Virden shaft in Illinois, there are two shaking screens 4 by 24 feet. One is hung in the usual way, and the other is set upon wheels, and this method, which is believed to be new, has given satisfaction. The wheels used are 14-inch tub wheels on 1½-inch axles, three pairs being used, and running on 10 by 12-inch pine stringers. The throw of the screen is eight inches.\* Self-tipping cages are used at this colliery, and they discharge the coal from the tubs on to a 12 by 20-foot bar screen. A conveyor takes the coal to the shaking screens mentioned above.

A novel form of screen has been built at the Coal Valley Mine in Iowa, and is stated to give satisfaction. The screen proper is made up of cast iron wheels set on shafting. The wheels are  $\frac{5}{8}$  inch thick, are spaced apart by washers  $\frac{1}{2}$  to  $1\frac{1}{2}$  inch wide, and have corrugated circumferences. There are nine shafts carrying the wheels, and they are all driven from a common shaft in the same direction. The screen is 9 feet square and is set at a slight slope.†

At the Congo Colliery in Ohio the coal is emptied from self-tipping cages on to a bar screen, and is then caught in a cradle which lowers it into the railway trucks. Under the bar screens are two wire-mesh shaking screens worked by cranks.‡

A form of tippler, designed by B. S. Randolph, has recently been illustrated.§ It is intended for end-tipping waggons, and consists of a base provided with horns to hold the axles. The underside of the base is flat at both ends and curved in the middle as a circle struck from a point lying between the centres of gravity of the full and the empty tub. The base has projections or teeth to engage the support on which it rocks.

**The Surface Plant at Kirkby Colliery.**—In a paper read before the Institution of Civil Engineers, T. Gillott || described the

\* *Engineering and Mining Journal*, vol. lxii. p. 608.

† *Ibid.*, p. 561.

‡ *Ibid.*, vol. lxiii. p. 259.

§ *American Manufacturer*, vol. lix. p. 873.

|| *Minutes of the Proceedings of the Institution of Civil Engineers*, vol. cxvii. pp. 176-183.

surface plant at Kirkby Colliery. The Kirkby pits, sunk to work about 10,000 acres of "top-hard" coal, were situated on the Nottingham and Mansfield line of the Midland Railway. The tubs in the pits were filled by hand, so the quantity of small coal sent to surface was only about 15 per cent. The nominal capacity of the tubs was 15 cwts., and they arrived at the bank in a two-decked cage simultaneously unloaded on two landings, one 7 feet 4 inches above the other. Lines of 2-foot 3-inch gauge were laid to allow the tubs to be weighed, tipped, and returned by the empty lines to the opposite ends of the cages. There were two tipplers upon each landing, on leaving which the coal descended a shoot having two superimposed screens, to remove a portion of the small coal, the large being delivered on to a travelling band, 3 feet 3 inches wide and 280 feet long, where it was freed from impurities by hand-picking. The waggons for picked coal ran alongside the band, which was 13 feet 6 inches above the rail-level, and were loaded at thirteen shoots arranged along its length. The gradient of the railway was with the load, so the waggons were lowered without motive-power; and to provide for the accidental running away of a waggon, the shoots were hinged to allow them to be swept clear by it. The residue from the travelling band was raised by an elevator to a cross-belt where any further impurity was picked out. This belt was divided down the centre by a bar so that all coal larger than a  $2\frac{1}{2}$ -inch or 3-inch cube was separated into hard and soft. The divisions were maintained over the jiggling-screens, so that hard cobbles were delivered by one shoot and soft cobbles by another into the trucks, the nuts and small slack falling into hoppers with bottom doors. The screens made about sixty or seventy double vibrations per minute, and the excentrics were set opposite to one another, so that no injurious vibrations were transmitted to the framework.

The arrangements for the railway traffic were such as to allow gravitational shunting and sorting as far as possible. The lines fell with a uniform gradient of 1 in 80 from north to south. Empty waggons were received from the Midland Railway by a line diverging into six dead-end sidings, from which they could be selected and run into any of the six loading roads. The empty waggons were weighed, and an average gain of 2·83 cwts. per truck had, during June 1895, been thus effected. The loaded waggons converged to the north weighing-machine, whence they passed into storage-sidings, the capacity of which amounted to 280 trucks, and then to the Midland or Great Northern Railway.

**The Preparation of Anthracite.**—W. D. Wight\* gives a detailed account of the plant for breaking and sizing anthracite at Glyn-castle Colliery, South Wales. It is chiefly intended for making nuts for domestic use, but other sizes are made. The rail level at the tippler is  $46\frac{1}{2}$  feet above the railway rails, and a long shoot is placed in line with the tippler and colliery screen, so that large coal can be loaded direct into the trucks. A special form of tippler has been designed for use here. It turns over sideways and has a variable speed, which is produced by interpolating cranks and a drag link in the driving motion. Eleven seconds are occupied in inverting the tram, and the coal is then emptied up to the twenty-sixth second. The second half of the revolution is completed in four seconds. The coal passes over a screen with bars an inch apart to separate small coal, which is weighed in a billy-fairplay. The large is picked over on a belt 14 feet long and 4 feet wide, which carries it to a screen with bars spaced  $3\frac{1}{2}$  inches apart. Coal passing through goes to a Klein screen, and the larger coal is loaded into trucks or taken to the first breaker. This consists of two cylinders geared together, 4 feet long by  $2\frac{1}{2}$  feet in diameter, and each studded with 1740 spikes, alternately 3 and  $4\frac{1}{2}$  inches long. The cylinders revolve a hundred times per minute. Broken coal is taken to the Klein screen above mentioned, where all coal failing to pass 3-inch square holes is separated and forwarded to the second breaker, which is of a similar type to the first. A second Klein screen takes the coal from the second breaker, and also the coal passed through the first screen, and delivers three classes, cobbles and first and second nuts, on to a picking belt, 80 feet long and  $4\frac{1}{2}$  feet wide, divided longitudinally into three parts. The nuts are swept off at each side and the cobbles delivered over the end. Coal below nut-size passing through  $\frac{3}{4}$ -inch square holes is lifted by an elevator and made into three sizes on a vibromotor screen. The larger sizes, beans and peas, are washed in a Murton washer.

**Coal-Washing.**—J. V. Schaefer † describes the washing of coal by the Lührig process. A 600-ton plant on this system is being erected at Greensburg, Pennsylvania, close to the Connellsville district. This plant is described by the author. It is designed to make eleven sizes, each to be washed separately. The nut-coal is washed before crushing. Three men only are required to run the plant, and complete arrange-

\* *Transactions of the Federated Institution of Mining Engineers*, vol. xii. pp. 238-256, with four plates.

† Paper read before the American Society of Mechanical Engineers, through the *Iron Age*, vol. lviii. pp. 1195-1198, with illustrations.

ments are made for settling the dirty water and drying the washed coal. Other plants on this system have been erected in America with successful results. At Bett, in Montana, the washed coal is coked in a hundred beehive ovens, whilst formerly the unwashed coal could not be coked successfully; and other installations have been put down in Illinois and Vancouver Island.

At the Hohenegger Colliery, in the Karwin district, is a coal-washing plant which is described by N. Herrmann.\* The Hohenegger Colliery began active operations in 1890, and a dry system of separation was at first employed, the available supply of water being but small. Six seams are mined, the coal being of the character general in the Karwin field. It is more or less shaly in character, and shows a strong tendency to dust. Dry systems of separation are almost entirely abandoned now in the Karwin field, having been replaced by wet methods. The author publishes eight illustrations showing the new wet plant that has been laid down at this Hohenegger Colliery. This consists in the main of a system of jigs and trommels, and it requires as a maximum 35 cubic feet of water for every 10 tons of clean coal. It is arranged to treat an output of 75 tons of coal an hour. The coal as mined contains on the average from 10 to 16 per cent. of ash, while the ash in the washed coal only amounts to from 5·5 to 7 per cent. When quite clean the coal contains from 2 to 4 per cent. of ash.

F. W. Hardwick,† in a lecture delivered at Mansfield, describes various methods employed in the mechanical separation and removal of impurities, also leading types of washing appliances, their construction and the principles of their action in washing and sizing.

An illustrated description has appeared ‡ of the Baum coal-washing apparatus.

A general view of the coal-washer at Braceville, Illinois, has also recently been published.§ The coal is taken by an elevator to a washer of the Robinson type.

Two photographic illustrations of a coal-washing plant erected near Sopris, in Las Animas County, Colorado, have been published.|| The coal is led by a conveyor 260 feet long to a height of 83 feet. Screen bars spaced  $1\frac{1}{2}$  inch apart in the conveyor-trough just below the head

\* *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xliv. pp. 537-540, with sheet of illustrations.

† *Colliery Engineer*, vol. xvii. pp. 161-163.

‡ *Colliery Guardian*, vol. lxxii. pp. 883-884.

§ *Engineering and Mining Journal*, vol. lxii. p. 511.

|| *Ibid.*, pp. 391-393.

remove small coal, which goes direct to a pair of sizing screens. The large coal is crushed, and joins the finer coal in these screens, which are 18 feet long by 6 feet in diameter, and perforated with  $\frac{1}{2}$ -inch and  $1\frac{1}{2}$ -inch square holes. The two larger sizes, nut and pea, are collected in bins, and the third size, a mixture of dust and buckwheat, is freed from dust by an air-blast. Conveyors take these three sizes to separate washers, and thence to the storage places. The troughs of the latter are perforated to drain the coal. Dust coal is not washed. Dimensions of the various conveyors, which are of the Jeffrey type, are given.

Illustrations have been published \* of the Scaife trough-washer. The body of the trough is semicircular, 2 feet in diameter and 24 feet in length, and is provided with dams at the bottom. The special feature is that one side of the trough is hinged, so that it can be turned down bodily to discharge the dirt. A longitudinal shaft with stirrers and the usual feeding and discharging appliances for coal are adopted.

**Loading and Unloading Coal.**—Illustrations are given † of appliances for handling coal for the Southern Pacific Railway Company, designed by J. D. Isaacs. The coal is lifted from a vessel's hold, and discharged into railway trucks by a form of grab manipulated by a travelling jib-crane.

Illustrations have recently been published ‡ of a large plant intended for unloading anthracite from ships at Chicago. There are four cranes on the dock, and each has a slewing as well as a traversing motion. Each crane has a cantilever projecting on one side over the vessel, and on the other over the conveying belts. A carriage running on this cantilever enables the skip to be lifted from the hold, run to the rear, and discharged automatically into pockets from which it is distributed over the storage floor by conveyors, of which details are also given.

An illustration is published § of a crane for lowering coal-waggons bodily into the holds of vessels, and discharging them from either end. A swinging jib lifts a tipping platform on to which the wagon is run, and the motions of both jib and platform are controlled by hydraulic cylinders through rope-gearing.

\* *American Manufacturer*, vol. lix. pp. 871-872.

† *Journal of the Association of Engineering Societies*, through the *Engineering News*, vol. xxxvi. p. 405.

‡ *Engineering News*, vol. xxxvii. pp. 82-84; *Iron Age*, vol. lix. No. 6, pp. 1-3.

§ *Iron and Coal Trades Review*, vol. liv. pp. 45-46.

K. J. C. Zinck \* describes the coal unloading and conveying machine at Gladstone, Michigan. The dock has a width of 500 feet and length of 800 feet, with a capacity of 300,000 tons of coal. A 15-foot gauge-line 30 feet above the dock carries eight hoisting machines, which are worked by steam supplied by valves at intervals on a 6-inch main. At right angles to the track at its back are 18-inch gauge lines inclining from 35 to 25 feet above the dock, and on these, trucks, holding  $1\frac{1}{2}$  ton each, run to carry the coal from the hoists to the piles or trucks.

**Coal-Dust Briquettes.**—Briquettes † are being made with coal-dust and bisulphite of lime solution, a waste product of paper-mills at Gömor, in Hungary, where there are also some charcoal-fired blast-furnaces, the waste gases from which are used to concentrate the solution. When the latter has attained the desired degree of concentration, it is led into a briquette machine, where it is intimately mixed with the coal-dust. The briquettes thus obtained acquire great hardness on drying. At first they were used as fuel instead of wood, and inasmuch as they gave out no disagreeable effluvium in burning, it was afterwards decided to use them in the blast-furnace. The injurious action of the sulphur contained in the briquettes was eventually counteracted by using a sufficient quantity of calcareous flux, causing the sulphur to pass off in the slag; and it appears that the results are now quite satisfactory.

In Velna's process of making briquettes, petroleum residue or mineral tar is used as a binding agent for culm and small coal. Briquettes are thus made for industrial purposes and for gas-making. For coking, the mixture is not made into briquettes, but is charged into the ovens in lumps. From 5 to 10 per cent. of the binding agent is used.‡

At a briquette-works near Kausche, in Germany, the air from the drying-ovens is passed through roomy brick chambers so as to deposit dust, which is then returned to the ovens.§

The plant at Blanzy used for making briquettes now consists of two works, one with three Révollier presses and the other with four Biétrix presses. For the former 9 per cent. of pitch is mixed with 91 per cent. of coal in a pugging-mill heated with steam. The pressure in the press is 142 to 156 lbs. per square inch. The briquette then contains about 4 per cent. of water. It is left on a conveyor belt for forty minutes, and then loaded into railway trucks. Two hundred and forty tons are

\* *Engineering News*, vol. xxxvii. pp. 69-70.

† *Génie Civil*, vol. xxx. p. 126.

‡ *Engineering and Mining Journal*, vol. lxii. p. 582.

§ *Ibid.*

made daily. The Biétrix presses make 330 to 340 tons daily, one briquette at a time.\*

Circular No. 5 of the Steam Users' Association contains the report of R. S. Hale of his visit to Europe to study boiler practice. He notes that dust-firing is meeting with considerable favour in Germany and England. The fine coal-dust is, however, not only a very dirty material to handle, but is also exceedingly liable to spontaneous combustion, and he does not consider that the problem of grinding and storing it has yet been commercially solved.

\* *Comptes Rendus Mensuels de la Société de l'Industrie Minérale*, 1896, p. 107.

## PRODUCTION OF PIG IRON.

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### I.—BLAST-FURNACE PRACTICE.

**Progress in the Iron Industry.**—In his presidential address to the American Institute of Mining Engineers, E. G. Spilsbury \* dealt with the improvements in mining and metallurgical practice during the last decade. Blast-furnace production has risen from 1000 tons weekly to 2500 tons, and even, it is stated, to 6500 tons at Duquesne, where two rows of tuyeres are being put in to supply the requisite quantity of blast. Automatic hoisting and charging appliances capable of handling 1700 to 3000 tons of material per day are replacing hand-labour and wheel-barrows. Improvements in heating the blast, in water-jackets, and other details are referred to, and also the process of casting pigs in chills instead of in sandbeds. As likely to play a prominent part in the Southern pig iron industry, reference is made to Talbot's process of desiliconising iron by pouring it through a bath of molten oxide of iron. In steel manufacture the automatic charging machine has had great effect, but the open-hearth process has not advanced so much as it might have done on account of the competition of the Bessemer process. The Bertrand-Thiel process, Campbell's tilting, and Wellman's tipping furnaces are also alluded to. The concentration of iron ore and the manufacture of ore briquettes are also mentioned.

In a presidential address to the American Society of Mechanical

\* Through the *Iron Age*, vol. lix. No. 8, pp. 15-18.

Engineers, J. Fritz \* deals generally with the progress of the manufacture of iron. From the primitive manufacture of pig iron early in the century, the developments are briefly traced up to the present day, through the use of anthracite in 1840, puddling in 1842, rail-mills in 1845, pig-boiling in 1848, the three-high mill in 1857, the Bessemer process in 1864, and the open-hearth in 1866. Turning then to machine tools, the author described the primitive appliances in vogue when he was apprenticed in 1838, especially the indifferent lathes and scanty tools, and these are compared with the heavy machinery now in use. His early experience led him to use cast iron instead of piled iron for shafts, owing to the difficulties of forging, and from this he diverges to hollow steel forgings and fluid compressed steel. The improvements in steel as applied to shafting are then discussed, and the present recognition of the elastic limit and reduction of area is dwelt upon, whilst tempering and the use of nickel steel are also discussed. Reference is also made to the advantages accruing from the employment of higher carbon steels than formerly.

W. O. Amsler † reviews the improvements in the design and construction of blast-furnaces, and gives a description of the furnace as at present constructed, and of the improvements coming into use.

In a review of recent progress in metallurgy, E. de Billy and E. Julhiet ‡ discuss the preliminary treatment of ores, magnetic concentration, roasting, the blast-furnace, the Bonehill puddling process, improvements in the Bessemer process, the Walrand-Legenisel process, the open-hearth steel process, the Stockman process, the manufacture of tin-plate, and, lastly, the attempts made to arrive at the unification of testing methods.

**The Duquesne Blast-Furnace Plant.**—Illustrated accounts § have appeared of the Duquesne blast-furnace plant of the Carnegie Steel Company, which consists of four furnaces with room for two more. The furnaces are placed in groups of two each with eight stoves in line between them, and each group has a separate blowing-engine equipment. The site for the first pair was in swampy ground, so piles 35 feet long were driven to the rock and surmounted with a grill of

\* *Iron Age*, vol. lviii. pp. 1089-1092; *Engineering News*, vol. xxxvi. pp. 381-383.

† *Sibley Journal of Engineering*, November 1896.

‡ *Bulletin de la Société d'Encouragement* vol. ii., Series 5, pp. 47-87.

§ *Iron Age*, vol. lix. No. 12, pp. 5-11, with illustrations and plates; *Engineering*, vol. lxiii. pp. 469-473, 538, with illustrations and plates; *Génie Civil*, vol. xxx. pp. 353-358, with illustrations and plate.

rails and then with concrete, forming a solid block of about 50,000 tons. The stockyard extends the whole length of the plant. It is excavated to a depth of 26 feet and has a breadth of 300 feet and is 1085 feet long. Its capacity is 600,000 tons of ore, or five months' supply. The ore bins are on the furnace side of the yard, whilst the limestone and coke bins are placed on the opposite side. There are thirty-six ore bins in one line, with counterbalanced shoots from which the ore emptied from the trucks can be removed either to the stock piles or to the furnace. Ore is taken from the stock piles by a bucket-conveyor, which works over the pile and has buckets which take a five-ton load. Coke and limestone are only stored in the bins, and not in the stock piles. The total storage capacity of the bin system is 9500 tons of ore, 3600 tons of coke, and 2200 tons of limestone. Three Brown cranes with a span of 233 feet command the yard, and each can handle 1500 to 2000 tons of ore daily, and at their centres are 58 feet above the floor level. Materials for feeding the furnaces are drawn from the doors in the bottom of the bins into buckets resting on trucks. The coke buckets hold 4000 lbs. and the ore buckets 10,000 lbs. The trucks for the latter have weighing platforms. These charging buckets are cylindrical shells of  $\frac{3}{8}$ -inch steel, 5 feet 7 inches external diameter, loosely placed on conical bottoms, from which stems pass upwards and by which they are suspended. The trucks are collected by a small locomotive and run to the foot of the lifts, which are inclined at 67°. Each furnace has its own lift. The bucket is caught by a hook on the elevator, and is prevented from swinging by a carriage or frame. At the top of the lift the carriage and bucket are manipulated by movable ways, so that the bucket is lowered. The shell is held by a fixed ring, whilst the bottom drops farther and depresses the gas-check bell, thereby allowing the contents to fall evenly on to the main bell. The bottom is then raised, allowing the gas-check bell to close, and as it rises it picks up the cylinder and is then removed. The main bell is carried by a crosshead from a lever which is worked by an oscillating cylinder. All these parts, including the main bell, are worked by the engineman who drives the hoist, so that no one is required on the top of the furnace. The time between picking up and returning a bucket has been cut down to  $1\frac{1}{4}$  minute. A branch from the hot-blast main is led along the bins to obviate any difficulties due to ice in winter.

The furnace stack is 100 feet high and has a diameter of 14 feet in the hearth, 22 feet boshes, and 17 feet at the throat. The entire bosh

is protected by bronze cooling-plates. Furnaces Nos. 1 and 2 have ten 7-inch tuyeres, while Nos. 3 and 4 will have twenty 5-inch tuyeres. The cubic contents of each furnace is 25,000 cubic feet. Gas is taken off by six flues into two downcomers, which wind half-round the furnace in opposite directions in a spiral form with an angle of 45°, and then unite in a dust-catcher 40 feet high and 28 feet in diameter. Explosion doors are provided at the top of the furnace and at frequent intervals along the gas flues.

The stoves, four to each furnace, are 21 feet in diameter and 97 feet high over all. They are of the Kennedy type, with a central combustion chamber tapering upwards from  $5\frac{1}{2}$  to  $6\frac{1}{2}$  feet in diameter, and an annular space filled with hollow bricks. Each stove has a separate chimney 130 feet high and 5 feet in diameter.

The casting-house is 219 feet long and 70-foot span, and is commanded by electric cranes. These handle the moulds for making the pig beds, besides their other work. About 1600 tons out of the daily make of 2200 tons will be taken to the steel-works, and later on probably even less will be cast into pigs.

Babcock and Wilcox boilers of 250 horse-power each are arranged in groups, giving 6000 horse-power for each pair of furnaces and are fired with gas, but coal may also be used, and the excess steam will serve the steelworks. For each group of furnaces there are five blowing-engines commanded by two 25-ton electric cranes. The engines are vertical cross compound condensing beam type with steam-cylinders 40 and 78 inches in diameter, air-cylinder 76 inches, and stroke 60 inches. The inlet valve is positively worked and the outlet valve is automatic. The ordinary speed is twenty-eight revolutions, giving blast at the tuyeres at a pressure of 15 lbs., but this may be raised to 25 lbs. One engine is held in reserve, and each group has one condensing plant. Four pumps of the vertical compound condensing type, with steam-cylinders of 22 and 14 inches, pump of 14 inches, and stroke of 36 inches, will give 20,000,000 gallons daily through a standpipe, and arrangements have been made to clear the muddy water drawn from the Monongahela River. Three 500 horse-power generators supply current for lighting and power purposes.

The blast temperature is 1000° F. and pressure 15 lbs. With ores yielding 57 to 60 per cent. of iron, the best month's record has been 17,182 tons, or 572 tons daily; the best week, 4110 tons; and the best day's output 690 tons. The best month showed a coke consumption of 1700 lbs. The limestone charge is about 25 per cent. of

the ore charge, which has been worked with 75 per cent. of Mesaba ores without difficulty.

Electric motors are extensively used at these works for working the cranes and other machinery. The cranes over the stockyard, those in the casting-houses, over the metal mixer, and over the pig-breaker are all driven by electricity, as is also the pig-breaker.\*

F. Hilton † also gives a short account of the Duquesne Works.

In a presidential address, J. M. Camp ‡ states that the two new blast-furnaces in blast at Duquesne, and the two others being built, are 100 feet high, 22 feet in diameter at the boshes, and 14½ feet in the hearth. The capacity of each furnace is about 570 tons of pig iron daily, and No. 1 furnace has made the unprecedented record of 685 tons in twenty-four hours. A radical departure in the new furnaces is that each will have twenty tuyeres. Numerous new features in the way of storage bins and machinery for handling the ore and limestone have been adopted, which will materially reduce the cost.

**The Manufacture of Charcoal Pig Iron.**—In discussing the smallest quantity of charcoal with which it is possible to smelt pulverulent iron ores in the blast-furnace, Odelstjerna § observes that the best result is obtained when (1) the form of the furnace shaft is shaped so as to obtain the maximum output, and (2) the ores are enriched up to a minimum contents of 75 per cent. of iron. It would be best, he thinks, to change in some ways the shape of the Swedish furnaces, particularly as regards their width at the throat and in the crucible, and to adopt generally the use of six to eight tuyeres. It is true, he observes, that it is not possible in general to blow more rapidly in these furnaces than is now done, without the chance of producing a poorer quality of iron and causing an increased consumption of charcoal; but if the crucible portion of the furnace is considerably widened and the tuyeres increased, care being taken to avoid too high a temperature in the crucible, which would be disadvantageous when making certain kinds of pig iron low in silicon, then it would be possible to put a much larger quantity of material through the furnace daily. The author points out that practice in the new Russian perfectly cylindrical furnaces shows that there need be no fear of any hanging

\* *Iron Trade Review*, vol. xxx. No. 10, p. 16.

† *Iron and Coal Trades Review*, vol. liv. pp. 295-296.

‡ *Proceedings of the Engineers' Society of Western Pennsylvania*, vol. xiii. p. 13.

§ *Wermåndská Annaler*, through the *Berg- und Hüttenmännische Zeitung*, vol. lv. p. 25.

up of the charge if the shafts are made, both above and below, far less conical than is now customary. By reducing the ore to the size of sand and then enriching it, a twofold saving of charcoal would be effected, as not only would the ore be higher in iron, but the reducing gases would have much greater facilities afforded them. In this connection certain American practice is referred to. To reduce the quantity of charcoal, too, the temperature of the blast used must be increased, and this could well be done if a slight increase were made in the quantity of limestone charged. The Gjers stoves at Detroit, 24 feet long and 20 feet broad, yield blast of a temperature of 800° C., whilst the small and therefore cheap regenerative stoves at Ashland yield blast of a temperature of 1000° C.

**Suggested Blast-Furnace Plant.**—A. Wolski\* discusses a blast-furnace plant arranged for the self-regeneration of its gas. He considers that existing blast-furnace plants, however good otherwise, are wanting in the perfect utilisation of the fuel. He discusses generally the various papers which have from time to time been published as to the theory of blast-furnace, practice and the use of caustic lime. He then passes to a consideration of various recent suggestions for the improvement of blast-furnace methods, and discusses these. Messrs. Sattmann and Homatsch, for instance, recommend a type of furnace which in reality consists of three furnaces placed one above the other, but which is charged as to ore exclusively from the top. There are tuyeres at various levels, and through these the waste gases can be injected after passing through regenerators. The solid fuel, coke, is charged in at the lower part of the furnace. In this way a fuel consumption of 30 parts of coke and 75 of good brown coal suffices for the treatment of 100 parts of roasted spathic ore containing 56 per cent. of iron. This the author doubts, but he is not aware whether the process had been tried in practice. He discusses the process theoretically and arrives at an unfavourable result.

Incidentally he refers to some blast-furnace results obtained in Russian Poland. He publishes two sketch elevations of the charcoal blast-furnaces at the Stomporkoff Works, in the government of Radom, as observed after they had been blown out. One of these was at work for 216 weeks, and was then blown out for the purpose of reconstruction with a view to use coke as fuel. The useful internal capacity of the furnace was 1236 cubic feet, and its average daily

\* *Stahl und Eisen*, vol. xvi. pp. 706-711, 869-875, and 911-915, with six illustrations.

out-turn 13 tons of grey foundry pig iron. Calcined clay ironstone was used with a yield of 34 per cent. of iron. The blast was heated to 350° C. in Langen stoves, and its pressure was about 100 millimetres of mercury. The charges made amounted to 130 per day. For each ton of pig iron made the internal capacity of the furnace was thus 95 cubic feet. For each ton of pig iron made 0·985 ton of charcoal was used. The slag made contained up to 23 per cent. of alumina.

The second blast-furnace at this same works was in blast for 120 weeks before being blown out for the same reason as the first one. It was a smaller furnace than the other, having an internal capacity of 847 cubic feet. At first, ores were used which yielded from 30·5 to 35·5 per cent. of iron, and the daily out-turn amounted then to 6·5 tons, or 130 cubic feet furnace capacity for each ton of pig iron made. The charcoal used amounted to 1·2 ton per ton of pig iron, the pressure of the blast being from 60 to 75 millimetres of mercury, and the other conditions identical with those of the first furnace. Subsequently red haematites from the Kriwoi Rog were used, the yield being raised to from 40·1 to 41·2 per cent., the daily out-turn then becoming 9 tons and the furnace capacity 60 cubic feet per ton of pig iron made. The furnaces were relatively very high for their width, the ratios being 7 to 1 and 7½ to 1. During the campaign the walls had been greatly eaten away in the crucible zone, the diameter a little above the tuyeres having been increased to 100 inches in the first case, as compared with the original diameter at the boshes of 82 inches. The other furnace was similarly enlarged, but to a lesser extent. Further information is given with regard to these furnaces, and the author draws attention to the advantage derived from rapid working in blast-furnace practice. This again, he says, is dependent on the degree of completeness with which the reduction of the ore is effected by the furnace gases in the indirect reduction. The author thinks that the carbonic oxide present in the furnace gases must be considered exclusively as a movable reduction atmosphere. He takes the following as representing the average composition by weight of the waste gas :—

CO <sub>2</sub> .	CO.	O.	H.	CH <sub>4</sub> .	N.	Total.
13·6	28·7	0·5	0·5	0·4	56·3	100·0

And he calculates that burnt with air at 0° C. this would yield a calorific intensity of 2026° C.

The author in his proposed modified furnace plant does not alter the external shape of the blast-furnace, but he takes away gas from a point

rather more than half-way to the throat above the boshes, and injects it with hot-blast as a blow-pipe flame at the top of the boshes. Above the gas take-offs he injects cold-blast.

The author devotes considerable space to a theoretical consideration of the question, considering in detail what takes place calorimetrically and otherwise in the different furnace zones. He gives illustrations of his proposed plant.

**Blast-Furnace Gas.**—A. S. Keith \* deals with the economical use of blast-furnace gases. A factor of primary importance is the separation of the dust by the use of dust-catchers on the downcomers, and both of these should be of ample size. In a furnace working on Cleveland ore, and making 600 to 700 tons of iron weekly, as much as two to five tons of dust is collected. Only one firm appears to use a baffle-valve in the downcomer connected to the bell, to prevent loss of gas when the latter is lowered. Pressure-gauges ought to be used on the gas mains, to give some guide as to the amount of gas burnt in the stoves, and more attention is required to regulate the supply of gas and air to the boilers. Self-regulating appliances might easily be adapted for this purpose, so as to avoid the heavy fall of temperature which often occurs. Brick-lined combustion chambers and flues of ample size should be used in the boilers, and should be kept clean. Some illustrations of boilers are given to show the brick chambers, and also to illustrate Tate's arrangement of regenerator chambers in the boiler seating for preheating the air supply. A number of boiler tests are given.

B. H. Thwaite, † under the title of "Pig iron as a possible secondary product of the blast-furnace," refers to the utilisation of the gas in gas-engines for generating electricity.

C. T. Jung ‡ observes that the question of the economical utilisation of blast-furnace gases has long received attention at the Burbach Iron-works. It was found that although a Parry cone with a central tube was used, much gas was lost, which, by using a second cover, might be collected. In charging in the ordinary way a considerable loss of gas results. At this works 5-ton coke charges are used, and the whole charge lowered at once. Calculating at least thirty seconds as the time required for a single charge, the loss per day will amount to some

\* *Proceedings of the Cleveland Institution of Engineers*, 1896, pp. 203-223.

† *Iron and Coal Trades Review*, vol. liv. p. 169.

‡ *Stahl und Eisen*, vol. xvii. pp. 180-181.

twenty-four minutes, during which period not only is the gas lost from the particular furnace in question, but also from the gas leads owing to equalisation of pressure, and the combustion at the stoves and boilers becomes unsatisfactory. It is therefore better to use wide gas-leads with low pressure rather than narrow leads and high pressure. The author thinks that, taking every loss into consideration, the real loss of a furnace losing twenty-four minutes per day in charging as above may really amount to an equivalent loss of sixty minutes in the twenty-four hours. Some 5 per cent. of the gas is lost, therefore, even under the most favourable conditions, and any improvements which diminish this loss are evidently of much value. Long ago a somewhat similar arrangement to that now introduced at the works in question was used at Hoerde by Von Hoff. The system was, however abandoned there, probably because at that time the quantity of steam required for use in the works was not so large as now, and consequently less satisfactory arrangements were adequate under the then existing circumstances. It is different now. The arrangement now adopted at the Burbach Works consists in using a secondary cover over the Parry cone with valve attachments, and some other modifications which the author describes. The gas escapes with a temperature of 35° to 40° C., and the author is of opinion that this same system will be adopted at all the other furnaces at this works as they are rebuilt.

It is stated that plant is to be put down to utilise the blast-furnace gases at Hoerde\* for driving gas-engines, and the power thus obtained will be employed to generate currents for electromotors and lighting purposes.

**By-Products from Blast-Furnace Gas.**—A. Gillespie† deals with the recovery of tar and ammonia from blast-furnace gases. The difficulties of treating the gases are twofold—the great volume and the high temperature. From a ton of coal about 10,000 cubic feet of illuminating gas is made, but from the blast-furnace 130,000 cubic feet are produced. The temperature of the gas in the collecting main is 300° F., and this must be reduced to 70° F. before ammonia is recovered; between these points the tar is deposited. The first attempts were made at Gartsherrie about 1880, and now nearly all the Scotch furnaces have recovery plant in some form or other. Practically, the

\* *Engineering and Mining Journal*, vol. lxii. p. 582.

† *Transactions of the Institution of Engineers and Shipbuilders in Scotland*, vol. xxxix. pp. 187-194.

removal of the tar does not affect the calorific value of the gas. At a plant recently erected for four blast-furnaces the clean gas raises steam in seventeen large high-pressure boilers, heats three regenerative stoves, and is also used for distilling and evaporating. The recovered tar yields 7 gallons of oil and 86 lbs. of pitch, and the ammonia liquor  $25\frac{1}{2}$  lbs. of sulphate of ammonium per ton of coal put into the furnace. The total recovery for 1895 from 92,940 tons of coal was 677,000 gallons of oil, 3550 tons of pitch, and 1057 tons of sulphate of ammonia. The green gas from the furnace is drawn by exhausters through the tar-washer—an oblong tank in which the gas bubbles through a layer of tar, depositing tar and distilling off the water. Next it passes through a pipe condenser, which may be cooled externally and consisting of eight chests, each containing eighteen pairs of 20-inch pipes 54 feet high. The lighter tars and weak ammonia liquor are deposited and are separated by gravity in another tank. The gas then passes in succession through two liquor-washers, of which the first is 60 by  $12\frac{1}{2}$  by 7 feet high and divided up by partitions into a serpentine path. Three Roots blowers capable of passing 900,000 cubic feet each per hour are placed between the washers. The second washer is fed with clean water, and the products, consisting of weak liquor and light tars, are used in the first washer and in the tar-washer. The tar, partially freed from water by the hot gases in the tar-washer, is distilled in wagon stills fired with gas. Ammonia liquor is treated with steam in vertical stills with horizontal trays. In these the ammonia is evaporated and is led into lead-lined vessels charged with sulphuric acid, from which it crystallises after boiling. Waste liquor from the stills is passed through settling tanks and used in the boilers and afterwards evaporated to dryness. The residue is burned and yields some potash.

A. Humboldt Sexton \* shows the importance of the blast-furnace in the industries, the vastness of the material which they consume and reproduce in another form, and describes what goes on in the furnace. He also shows the value and use made of the by-products and gives the history of the pioneers of the recovery process.

**Removing the Dust from Blast-Furnace Gases.**—F. W. Lürmann † illustrates arrangements for facilitating the removal of dust deposited from blast-furnace gases. This removal is effected either by dry or wet methods. Despite the prior separation of the dust by

\* Paper read before the Philosophical Society of Glasgow.

† *Stahl und Eisen*, vol. xvi. pp. 955-959, with eight illustrations.

various contrivances, some still settles in the pipe-ways which conduct the gas to the boilers and hot-blast stoves, and it is to arrangements proposed for the removal of this that the author refers. To enable these to be adopted, the pipe lines must be above ground and must be made of sheet iron. The inner diameter of these pipe lines depends on the quantity of gas to be passed through them, and should be from 20 to 39 inches. The larger the diameter of the pipe the lower is the velocity with which the gas passes through them, and the greater, consequently, is the quantity of dust which is deposited in them. This dust ought to be removed as deposited without any one having to enter the pipe lines and without causing any disturbance in the progress of the works operations. To facilitate the removal of the dust withdrawn from the pipe line, it is placed sufficiently high to enable waggons to be run beneath it into which the dust can be discharged. Up to 1885-86 these pipe lines were provided at intervals both above and below with openings provided with covers or valve arrangements. From time to time operations at the works were stopped, the covers to the openings removed, and subsequently boys passed through the pipes and cleaned the dust away from them. Since that date, however, this process has undergone improvement. In accordance with the author's own suggestions at Haltingen and Steele, modifications were introduced in 1884 and 1886, which he illustrates. At the lower sides of the large pipes, of which the gas lines were constructed, dust bags or pockets were arranged at intervals of 11·8 feet from centre to centre. These pockets were open below, but were provided with covers which kept them sealed when in use. Through these the dust was subsequently removed; but this removal, too, was only possible after the works had been temporarily closed down. In laying down a new plant in 1890 at the Geisweide Ironworks, these dust-pockets were placed so close together that there was practically no ordinary portion of pipe line between them, and all dust could be withdrawn through them. A channel-way, too, was arranged below their openings, and the dust could be withdrawn from them without stopping the works. To diminish, or even avoid altogether, the large number of dust-pockets necessitated by this arrangement, the Ilsede Works suggested placing in the pipe lines sloping pieces of metal, down the faces of which the dust could constantly pass into the openings, and the author subsequently introduced a further modification of this, in which these metal projections were in turn avoided, and their sloping faces replaced by the sloping faces of the dust-heaps them-

selves, which were allowed to form in the pipes. The sectional area of the dust-free space above the dust covers, assuming their angles to be 45°, is 25 square feet when the pipes themselves are 6½ feet in internal diameter. This free area corresponds to a pipe line of 5½ feet in diameter. The author illustrates the arrangement he adopts. At Ilsede a pipe line 5½ feet in diameter had such openings arranged at distances of 5½ feet, the openings themselves being 4½ feet across; but here, as only very fine dust is deposited in the pipe lines, the previous purification being a good one, the angle of 45° is too flat to cause the dust to roll freely, and the dust-heaps are higher than this angle would indicate. At Charlottenburg the angle is only 40°, yet a satisfactory separation results. The author illustrates other modifications and also describes an arrangement in which a constantly-moving brush arrangement within the pipes clears away the dust continuously. Endless-chain motion is used, and the first cost of the arrangements, including that of the electric motor necessary, is estimated at a little less than £3 per yard of pipe line.

In connection with F. W. Lürmann's paper on this subject other details are now published. O. Hahn \* states that at the blast-furnace plant of the Alfred Works, belonging to the Wissen Mining and Smelting Company, the old gas leads were removed in the summer of 1896 and replaced by others of a modified form. In the former plant the gas passed through a wide iron lead over a broad surface of water, the lead consisting of an open rectangular trough inverted into a wide and shallower saucer-like iron channel filled with water, which formed a valve, preventing the escape of the gas. The dust, collecting, settles in this water-filled saucer, and can readily be removed. The disadvantage of the method lies in the fact that the water in the trough gets heated, and the gas itself charged with water vapour, which is objectionable in the after-combustion of the gas. The old system has been replaced by round pipes 9 feet 10 inches in diameter provided with dust pockets with centres about 10 feet 7 inches apart, a space of 3 feet 10½ inches remaining between the pockets. This must soon get covered by a dust cone. The question then was how to remove the dust without interfering with the continued use of the gas conduit. O. Hahn shows by illustrations how this was effected by means of valves closing the apertures of the dust-pockets and a series of hanging rods which can be moved, and on moving throw the dust masses of the dust cones into the pockets. These rods are hung midway in the

\* *Stahl und Eisen*, vol. xvii. pp. 55-58, with four illustrations.

space between two pockets. This system of clearing the pipes by means of swinging pendula is evidently only applicable in the case of wide leads. Another system long in use at the same works is adapted for narrower leads, though it may also be employed in wider conduits. These narrower leads are provided with fewer openings, and a sledge-like appliance provided with shovel-plates is drawn backwards and forwards through the leads twice once a day and the dust collected in the pockets, which are closed by valves and immediately emptied. Another method in which a water valve is employed is also mentioned. The bottom part of the leads is of plates strongly inclined and terminating in relatively narrow shoots dipping into water. This water keeps quite cool and the gas scarcely comes into contact with it, consequently taking up scarcely any water vapour.

All these methods, however, only provide for the collection of that portion of the dust which settles by gravity, and does not affect the very small particles which are carried forward by the gas stream. These contain large quantities of alkalies, and are consequently very destructive to hot brickwork, such as that of the stoves. Even in wide conduits, with a section of 129 square feet, and 82 or 98 feet in length, these very fine particles cannot be brought to settle, while the quantity of gas sent through this was only such as to suffice for three Cowper stoves. No matter what course the gas is made to take, these very fine particles cannot be made to separate by gravity in even large pipe lines. It is therefore desirable to give each furnace its own pipe line, and only to allow the gases to come together when as much of this dust has separated as it is possible to collect. The author mentions the use of a large dry dust-collecting chamber in which a series of wire nets are arranged, well protected from explosion. Provided the pig iron being made is not high in manganese, the gas escaping is quite free enough from dust to admit of its being used in the hot-blast stoves without any fear. If spiegeleisen with more than 12 per cent. of manganese, or some other irons, are being made, this is not the case. A wet separator was therefore added to the dry one, in which a series of very narrow Körting injectors were made to play upon the gas. To free the gas from water spray and to collect the dust after this treatment the gas was exposed to water jets. Much dust is collected in this way, and the gas leaves the collector fairly dry, and with an average temperature of 16° to 22° C. The gas passes through another chamber to collect any drops of water, and then passes to the stoves, in which it burns with a clear flame and does not attack

the brickwork. So little slag is formed that during eight years' work repairs have been quite unnecessary. The blast has a temperature of from 800° to 900° C., or even higher. For ferromanganese with more than 30 per cent. of manganese, further precautions would have to be taken. Somewhat similar arrangements to some of those just described as hitherto in use at the Alfred Works are employed at Resicza, and are described by W. Schmidhammer.\*

**Improvements in Hot-Blast Stoves.**—C. T. Jung,† blast-furnace manager at the Burbach Works, observes that the building of No. 5 furnace at this works afforded the opportunity of introducing various improvements of greater or lesser importance, and these he describes. The Cowper stoves especially were largely altered. The question whether in the case of Cowper stoves a cast iron grid or one of fire-resisting material should be employed, is probably distinctly decided now in favour of the latter, mainly in view of the constantly necessary repairs which the use of the cast iron grid necessitates with its frequent breakages and consequent fall of brickwork. A further objection to the use of cast iron lies in the unequal expansion of this and of the brickwork, the result being that the latter is in constant movement, or at least that portion of it immediately resting on the grid, thus inducing considerable wear. By making the grids of fire-resisting material these difficulties are avoided, as they are both made of the same material. Still it must be admitted that the numerous grids of firebrick have been in many ways unsatisfactory when compared with grids of cast iron. They are more difficult to keep free and to clean, and the free space below the grid is considerably diminished. This difficulty does not occur when cast iron grids are used, while in this case, too, repairs are very readily effected. At the Burbach Works the difficulty of the wearing away of the brickwork immediately resting on the grid has long been partially remedied by making the weight of the main brickwork of the stove rest archwise on the supporting brickwork, but the result was not entirely successful, as bricks from the upper sections were apt to fall. Other disadvantages connected with the usual firebrick grid methods of construction are also referred to, and the author then proceeds to describe the system of firebrick grid constructions as patented by Puissant d'Agimont, which has now been adopted at the Burbach Works. This he illus-

\* *Stahl und Eisen*, vol. xvii. pp. 58-59, with two illustrations.

† *Ibid.*, pp. 174-180, with seven illustrations.

trates. This arrangement possesses all the advantages of that previously in use, and it is not liable to clog. Another improvement introduced into the construction of these Cowper stoves lay in diminishing the thickness of the bricks towards the top of the stove, thus enabling an increased heating surface to be obtained, and ensuring a better utilisation of the gas. It has hitherto been customary in the construction of Cowper stoves to make the cellular spaces possess exactly the same diameters throughout the entire stove; but this is by no means an ideal arrangement, and is indeed entirely illogical. Experience has shown that a brick 50 millimetres (1.97 inch) thick takes up the heat most rapidly, and similarly gives it up again with the greatest freedom, and that thicknesses of 70 millimetres (2.76 inches) and more are distinctly unsatisfactory for similar use, and this free play can be readily utilised by increasing or diminishing the thicknesses of the bricks by  $2\frac{1}{2}$  or 5 millimetres at certain intervals.

At the Burbach Works for the four older blast-furnaces fourteen Cowper stoves are in use, seven for each of the groups of two furnaces. The dimensions of the cellular spaces in the six stoves first erected were 100 by 100 millimetres, and in the more recent ones 120 by 120 millimetres. These may be considered somewhat small, still good results have been obtained, and blast temperatures of from 800° to 830° C. are obtained with 18-metre stoves. The stoves in future to be erected will be somewhat different, and allowing a total height of 20 metres, a cellular space to begin with of 120 by 120 millimetres and a thickness of brick of 70 millimetres, with a gradual 5-millimetre diminution, the dimensions would be:—

4 metres, bricks 70 mm. thick, 120 × 120 mm. space = 144 sq. mm.						
4     "     "     65     "     125 × 125     "     = 156     "						
4     "     "     60     "     130 × 130     "     = 159     "						
4     "     "     55     "     135 × 135     "     = 182     "						
4     "     "     50     "     140 × 140     "     = 196     "						

Next is shown the proportion that would exist if a  $2\frac{1}{2}$  mm. reduction of thickness were adopted instead of one of 5 mm.

A third improvement introduced into the new Cowper stoves at this works consists in the use of perforated bricks. This the author considers to be of the greatest importance, as it ensures a far better distribution of the pull exerted by the draught of the stack throughout the whole stove, and a consequent far better general working. The heating surface is also increased in this way. The author deals fully with these perforations, and enumerates a number of advantages connected

with their use, and gives illustrations in explanation of his description. Actual experience as to their use has not yet been obtained.

F. W. Lürmann \* illustrates some new forms of bricks which have been recommended for use in hot-blast stoves. No special description is given, but the illustrations show the shape of the bricks themselves and the way they are built into the stoves. In tabular form, however, a comparison is made between the relative value of the bricks mentioned for the purpose for which they are intended. Six kinds are tabulated. The best results are shown to be given by a form of brick described by B. J. Hall † for use in the Ford and Moncur stove, and the worst for a form recommended by J. Kennedy.‡

**Blowing Machinery.** — A description of American blowing machinery is given by J. Birkinbine,§ and is illustrated by a large number of views of the various types. These include several types of fans, Roots, and similar positive blowers; a vertical compound beam blowing-engine; a horizontal twin Bessemer blowing-engine, with positive inlet and automatic outlet air-valve gear; a cross compound tandem horizontal blowing-engine; a vertical compound condensing blowing-engine; a beam blowing-engine; two Butt types of blowing-engine; a vertical cross compound blowing-engine; a horizontal tandem-engine; and the valve gear of a Weimar blowing-engine.

Other illustrations of a Weimar blowing-engine have also been published.|| It has a 42-inch steam-cylinder and 84-inch air-cylinder, with a stroke of 60 inches. At 45 revolutions and 20 lbs. of air-pressure it delivers 17,000 cubic feet per minute. The valves are placed round each end of the cylinder.

Illustrations are published ¶ of vertical blowing-engines constructed for the blast-furnaces at the Rhenish Steelworks, Ruhrtort. With 60 revolutions 57,566 cubic feet are to be drawn in and a blast pressure of 1·1 atmosphere to be produced. Some dimensions are as follows:—Diameters—High-pressure cylinder, 52·7 inches; low-pressure cylinder, 78·7 inches; air-cylinder, 86·6 inches, with a stroke of 70·8 inches in each case. The engine is further described.

\* *Stahl und Eisen*, vol. xvi. pp. 907-908, with six illustrations.

† *Journal of the Iron and Steel Institute*, 1896, No. I. pp. 20-52.

‡ *Iron and Coal Trades Review*, vol. liii. p. 214.

§ *Cassier's Magazine*, vol. xi. pp. 108-128.

|| *Iron Trade Review*, vol. xxx. No. 4, pp. 8-9.

¶ *Stahl und Eisen*, vol. xvii. pp. 132-135, with two illustrations.

Illustrations are published by C. Volk \* of the Lange valve. A brief description of the valve is also given. A blowing-engine equipped with these valves, used in connection with the blast-furnace at Vajda-Hunyad, Hungary, which at 40 revolutions draws in 24,720 cubic feet of air, is stated to be capable of being kept in constant work at a speed of 60 revolutions, a fact which, the author observes, speaks very well for the valves.

**The Scholtz Charging Appliance for Blast-Furnaces.**—This consists of a modified cup and cone, with central take-off for the gas, and is an improvement on the Buderus system. Drawings are published of this arrangement, which is stated to work very satisfactorily. †

**New Lifting Appliances at Blast-Furnaces.**—A new German hydraulic lifting appliance, which is stated to have been introduced into use at numerous works, is illustrated in *Stahl und Eisen*. ‡ It is stated to be a simple appliance, cheap, and easy of manipulation, which would be especially useful in replacing the older pulley appliances in rolling-mills.

C. Canaris § publishes a description with plans and photographs of the elevated line at the Niederrhein Works, Duisburg-Hochfeld, and of the electric crane plant employed. He points out that blast-furnace plants which have to deal with large quantities of raw material require now-a-days more than ever to pay attention to the adoption of arrangements which admit of the cheap and rapid transport of the raw materials to the furnaces. These he refers to. The Niederrhein Works adopted other arrangements prior to January 1894, but as from the commencement of that year it became necessary to unload the cargo-boats with greater rapidity, the present arrangements were introduced. Various difficulties had to be overcome, and the author describes in detail the arrangements introduced. There are two electric cranes in use, each of which lifts a ton and a half through a height of 39 feet with a speed of 23 inches per second. Hoisting and turning can be performed simultaneously. Each crane is served by an electro-

\* *Oesterreichische Zeitschrift für Berg- und Hüttonwesen*, vol. xliv. p. 87, with two illustrations.

† *Ibid.*, pp. 88-89, with five illustrations.

‡ *Stahl und Eisen*, vol. xvi. pp. 889, with two illustrations.

§ *Ibid.*, vol. xvii. pp. 1-4, with two plates and photographs and illustrations in the text.

motor, which at 110 volts and 875 revolutions develops 25 effective horse-power. The ore is then conveyed to the furnace by means of a continuous ropeway, which can be employed when one or both of the cranes are at work. The power necessary to drive this is 1·5 horse-power. Each ore waggon contains from 1 to 1·5 ton of ore according to its specific gravity. These arrangements have now been in use for four years and have given constant satisfaction.

**Blowing-in a Blast-Furnace.**—The blowing-in of a new blast-furnace at Tonawanda, New York,\* in December, had some interesting features. The President of the United States touched, in Canton, Ohio, the button which caused the fires to start. The operation is a striking illustration of modern electric appliances. Circuit was completed between one of the furnace dynamos and wires round the furnace. At each of the seven tuyere openings there was placed a glow-lamp, with the glass removed and with gunpowder placed round it. The powder in turn lighted cotton-waste saturated with paraffin, and the waste led through the openings into the furnace and communicated with the kindling wood below the coke. The capacity of the new blowing-engine is 250 tons daily.

A section has been published † of the new blast-furnace of the Tonawanda Iron and Steel Company near Buffalo, New York. This furnace has a capacity of 250 tons, is 80 feet in height and 18 feet in diameter at the boshes. It is equipped with three 18 by 80 feet Kennedy-Cowper stoves. The diameter of hearth is 11 feet, height to reducing cone 7½ feet, height to boshes 13 feet, diameter inside top of furnace 13½ feet, diminishing to 10 feet. There are seven 6-inch tuyeres. A very large blowing-engine supplies blast.

**Direct Castings from the Blast-Furnace.**—W. H. Butlin ‡ states that castings are made direct from the blast-furnace at Irthingborough in Northamptonshire, wheels, valve seatings, piston rings, and other articles being successfully produced. The results are attained by carefully selecting the ores and working the furnace at a low temperature with an acid and readily fusible slag. The author urges a plan for the scientific treatment and judicious mixing of Northamptonshire iron ores and for their smelting at comparatively low temperatures of heated

\* *Colliery Guardian*, vol. lxxii. p. 1063.

† *American Manufacturer*, vol. lix. p. 835.

‡ *Iron and Coal Trades Review*, vol. liv. pp. 507-508.

blast, from 850° to 950° C. being most suitable to the materials smelted in the district. In this way uniformity and an improved quality of the resulting product are obtained. Further, the contention is that a larger proportion of foundry metal is turned out, the castings made are stronger and more trustworthy, and a greater or less control is obtained over results than has, perhaps, been usually considered possible in similar circumstances in producing castings direct from the blast-furnace.

**Pig-Breaker.**—Illustrations have been published \* of a hydraulic pig-breaker capable of breaking 120 pigs per hour into four pieces each. The pig is fed by hand over a roller under the short arm of a lever, and held by a wedge whilst water is admitted to a cylinder under the long end of the lever.

**Injury to the Eyes of Ironworkers.**—In the mining and foundry districts of Bochum, Prussia, Dr. Nieden reports that during 1894 to 1895 patients engaged in these industries to the number of 5443 were treated. Of these, 68 per cent. were eye accidents, chiefly amongst the ironworkers. In both years, the percentage of accidents to the right eye was 56, as compared with 44 for the left eye.†

A description is given by Freudenberg ‡ of the different kinds of spectacles introduced for the purpose of protecting the eyes of workmen in ironworks and elsewhere.

**The First Coke Blast-Furnace of the Continent.**—With reference to the question as to which was the first real coke blast-furnace erected on the Continent of Europe, F. Büttgenbach § points out that the first coke furnace was erected fourteen years earlier than stated (in 1782), by an Englishman named Wilkinson, at Le Creusot, in France. This is shown by a brass plate at the Le Creusot Works, with an inscription to the following effect:—“Year of the Christian era 1782; the eighth of the reign of Louis XVI. During the period of office of M. le Minis. de la Choix-Castries; M. Ignaez Wendel de Hayance, Commissaire du Roi; M. Pierre Touffaire, engineer. This foundry, the first of its kind in France, has been built to smelt iron ore with coke, according to the method brought from England and put into practice by M. William Wilkinson.”

\* *Iron and Steel Trades Journal*, vol. lx. p. 207.

† *Engineering and Mining Journal*, vol. lxiii. p. 279.

‡ *Stahl und Eisen*, vol. xvii. pp. 283-285.

§ *Revue Universelle des Mines*, vol. xxxvi. p. 241.

**The Pig Iron Industry of France.**—A detailed account is given by A. Pourcel \* of the present state of the pig iron industry in France. The author first discusses in detail the chemical and physical properties of the metal, and its grading, and then briefly reviews the geographical distribution of iron ore, after which he shortly treats of the origin and rise of the blast-furnace. Sections are given of a modern English blast-furnace with a vertical shaft and of one of the modern German furnaces at Friedenshütte. The increase in size which has led to a daily production of 100 to 120 tons on the Continent, and of over 350 tons daily in America, is touched upon, together with the complications in the accessory plant, and then the history and effect of the hot-blast are traced. The second section of this part of the article deals with the influence of the structure, shape, and size of the blast-furnace on its production of pig iron. In Cleveland and Durham the furnaces were increased greatly in size without proportionately increasing the blast facilities, and this led to a reduction of dimensions, but it is now agreed fairly generally that increased capacity means increased production, together with economy in fuel, as long as the size is such that the materials of the charge are not crushed. By developing the blast the Americans have, with large furnaces, made as much as 500 tons daily. A number of sections of typical furnaces are then given to show the shapes adopted for facilitating the descent of the charge. The boshes are enlarged, placed at two-fifths the height of the furnace, and are double the diameter of the hearth, and the throat is not less than two-thirds the diameter of the boshes; and this is typical of Europe, England, and America. A number of examples of furnace working in various countries are then given, after which the reactions in the furnace are discussed with reference to the work of Bell, Gruner, and the author himself. Tables relating to the action of carbon monoxide and anhydride on iron and its oxide are quoted from the works of Sir Lowthian Bell, and it is shown what a favourable influence the rapidity of the gaseous current has on the reduction of ores. Akerman's results of the action of equal volumes of carbonic anhydride during equal times at different temperatures are also quoted and commented upon, and then the quantity of carbon burnt at the tuyeres is discussed. The calorific balance of the furnace is also dealt with, and a table from Ledebur is given. The arrangement of the furnace in order to ensure an equable distribution of heat is illustrated by a reference to Howson and Hawdon's blast-furnace at Newport-on-Tees.

\* *Revue Générale des Sciences*, 1896, pp. 465-475, 510-543.

A section is then devoted to the distribution of blast-furnaces in France, and the statistics of that country and of the world are summarised.

The part of this article relating to the chemical reactions is translated and commented upon by A. J. Rossi.\*

**Blast-Furnace Practice in Upper Silesia.**—F. G. Bremme † states that the Upper Silesia brown haematites contain from 0·02 to 0·2 per cent. of phosphorus, and the ore is consequently, as a rule, both too high in phosphorus for the acid, and too low in phosphorus for the basic Bessemer process, if smelted without the addition of other ores. In addition to the small quantity of clay ironstone found, puddle cinder from former working, and forge and other cinders have been used in the blast-furnace. Spathic iron ores from Styria and Hungary, and, in addition to the magnetites from Grängesberg and Gellivara, high-percentage ores from other sources are also smelted. The Swedish magnetites form, however, the most important foreign ore supply.

In 1895, the blast-furnaces of Upper Silesia smelted 1,241,000 tons of ore and ferruginous slag. Of this quantity 605,000 tons of ore and 175,000 tons of slag were from home sources. The total quantity of limestone and dolomite used as flux amounted to 375,000 tons. The annual out-turn of pig iron is 568,600 tons from eleven works with 26 active blast-furnaces. The average out-turn per day per furnace is thus 60 tons. The highest production is from the Friedenshütte, which averages 110 tons per day per furnace. During the past decade considerable improvements have been made, not only in the blast-furnaces used, but also in the hot-blast stoves and blowing-engines, the introduction of brick stoves being the most important improvement. All the furnaces in use are provided with the Lürmann slag tuyeres, and nearly all employ the Lange bell. This is liked in Upper Silesia, especially on account of the fact that it makes the interior of the furnace more readily accessible from the top than any other similar arrangement, the difficulty to be overcome being the clearing away of the zinc accumulations which have so constantly to be dealt with. The Upper Silesia brown iron ores contain from 2 to 3 per cent. or more of zinc, and this, in addition to leading to these accumulations, also causes a largely increased consumption of fuel. The height of the furnaces varies from 45 feet 6 inches to 65 feet. The height of the furnaces has been increased as the percentage of lump ore increased.

\* *Iron Age*, vol. lix. No. 6, pp. 12-13.

† Paper read before the *Verein deutscher Eisenhüttenleute*, September 20, 1896.

The furnaces smelting charges with high percentages of the Upper Silesia brown haematises have been kept low. Locomotives are now almost entirely employed in the transport of the slag in place of the hand and horse labour in use a few years ago. The old vertical form of blowing-engine has been replaced largely by more rapid working horizontal blowing-engines, capable of delivering the blast at a much higher pressure. The boilers for steam-raising are now nearly all heated by the waste gases from the blast-furnace. The Lürmann system of firing has been found to give much satisfaction. Of the 568,600 tons of pig iron produced yearly, about 61 per cent. is forge iron, 22 basic, and 7 acid Bessemer iron, 2 per cent. spiegeleisen, and 8 per cent. foundry pig iron.

**Hungarian Ironworks.** — The charcoal furnace at Govasdia is 12 miles from Vajda-Hunyad. It is 36 feet in height,  $4\frac{1}{2}$  feet in diameter between the two tuyeres by which the furnace is blown,  $8\frac{1}{4}$  feet at the boshes, and  $5\frac{1}{2}$  feet at the throat. The capacity of the furnace is 1580 cubic feet. A two-cylinder vertical blowing-engine is driven by a water-wheel of 30 horse-power. In 1895 it made 8442 tons of grey, white, and mottled pig iron and 205 tons of castings.

The Vajda-Hunyad Ironworks has three charcoal blast-furnaces and one coke furnace. The first furnace was put into blast in 1884, and the second was blown-in in 1885. This is still in blast. The third furnace was blown-in in 1891. It has a cubic capacity of 3880 cubic feet. These furnaces have each four tuyeres of from 3·9 to 7·8 inches in diameter. The blast has a pressure of from 60 to 80 millimetres of mercury. The blast is heated by three Whitwell stoves, each 12 metres in height by 5 in diameter, and by three iron pipe stoves. In 1895 the three charcoal furnaces made altogether 49,395 tons of pig iron and 1300 of castings. The coke furnace was blown-in in August 1895. It has a height of 59 feet, and an internal capacity of 10,200 cubic feet. The diameter at the boshes is 19 feet, at the throat  $10\frac{1}{2}$  feet, and at the tuyeres  $8\frac{1}{4}$  feet. There are six tuyeres. Water-cooling is employed for the armouring of the lower part of the furnace. The capacity of the furnace is 100 tons of Bessemer pig iron a day. Horizontal blowing-engines are used, and the blast is heated by three Whitwell stoves, each  $52\frac{1}{2}$  feet in height and 20 in diameter.

The Kronstadt Mining and Smelting Company possesses mines in the

Hunyad district which have an output of 24,000 or 25,000 tons a year. They are connected by a tram-line with a blast-furnace at Kalan. This makes 10,000 tons of pig iron a year, using a mixture of coke and charcoal as fuel. The foundry there makes from 2000 to 2500 tons of castings annually from 3 cupolas. Details are also given for another small ironworks and for a mining company in the Hunyad county.

In the Krasso-Szörenyer county between Dognácska and Vaskö are iron ore deposits of magnetite and red haematite which have a thickness of 30 yards. Ore pieces up to 3 cubic yards in size are found on the slopes of the Varto range. These consist of red haematite and magnetite of excellent quality, and are concentrated in a well-arranged washing plant which yields between 3000 and 4000 tons of washed ore per annum. In the Vaskö, Dognácska, and Tirnova districts 132,140 tons of iron ore were raised in 1895. At the Reschitza Ironworks two charcoal blast-furnaces made in 1895 18,817 tons of pig iron, and a coke blast-furnace 14,865 tons in 259 working days. The blast-furnace at Bogsán makes 4820 tons of forge pig iron per annum. At Anina there are two blast-furnaces. These made in 1895 31,235 tons of pig iron. At Dognácska there are two charcoal blast-furnaces 38 feet in height, one of which made 3295 tons of pig iron in 1895. Two charcoal furnaces at the Ruskitz Works are a little larger than these, and these, together with several other small ironworks and foundries, are also described.

The charcoal blast-furnace at Nyustyan is a little less than 33 feet high, and produces from 110 to 120 tons of grey pig iron a week. At Likér, in the immediate neighbourhood, are three coke blast-furnaces, which have already been described in these abstracts.

At Ozd is a steelworks provided with eleven puddling furnaces in operation, with regenerative firing and three trains of rolls. There is also an open-hearth plant provided with four Batho furnaces. This plant is served by several electromotors, and it has an annual output of about 50,000 tons; other steelworks, sheet-mills, &c., are also referred to, but these have been largely dealt with in previous abstracts.\*

**New Russian Ironworks.**—An account is published,† derived from an official publication, of the present state and future prospects of the mining and metallurgical industries in the district adjoining the

\* *Berg- und Hüttenmännische Zeitung*, vol. iv. pp. 339-342.

† *Stahl und Eisen*, vol. xvii, pp. 228-230.

Sea of Azov. Of the new undertakings in this district three require especial notice. The most rapid progress being made is shown in connection with the Mariupol Works. A pipe-mill has been nearly completed. The pipes are to be made for the Michailowo-Batoum petroleum pipe-line, which is to be 84 miles in length. An open-hearth plant is in course of erection, two basic furnaces being under construction. The pipe-mill is arranged for a production of from 80 to 90 20-foot pipes in the ten-hours' day. A rolling-mill for boiler-plates is also under construction, but armour-plate will also be made. Two blast-furnaces are also to be put up.

The Taganrog Works, in this same district, is also making rapid progress. A blast-furnace plant, foundry, open-hearths, rolling-mill, and shops constitute the plant. The ore to be used in the blast-furnaces will be mined partly on the spot, and in part obtained from the Donetz basin, and partly by sea from Kertsch, where mining is now being carried on by this company.

The third new works referred to—the Petrowsk—belongs to the Russo-Belgian Company. Orders for rails have already been booked in such quantity as to ensure work for some years to come. Two blast-furnaces, a Bessemer plant, and rolling-mill have been erected. The latter is stated to be one of the best in Europe. An open-hearth plant, foundry, and workshops have also been erected. This works is to be started in June 1897. Coal is found at a distance of  $2\frac{1}{2}$  miles from the works, and the works will be well supplied with fuel from this source.

The largest and at the same time the oldest ironworks in South Russia, the Jusow Works, is erecting a large Bessemer plant and rolling-mill. This works already produces 13,000,000 poods of pig iron annually, and some 5,000,000 poods of rails (say 210,000 tons and 80,000 tons respectively). After the completion of the new plant the possible out-turn of rails will be doubled.

**Iron Industry in the Ural Mountains.**—J. Kowarsky,\* describes the iron industry of the Ural Mountains, as shown by the Nijni-Novgorod Exhibition in 1896, where about a hundred of the existent 110 works were represented. Many of the furnaces, although belonging to one owner, are very widely scattered. Of the wood cut in the district, 45 per cent. is turned into charcoal, 50 per cent. is used direct as fuel, and 3 per cent. for building. The ores are found over millions

\* *American Manufacturer*, vol. lix. pp. 731-732.

of square miles, and vary greatly. The Northern Ural, of Jurassic age, produces spathic ore, and the Southern Ural is rich in other ores. The ores are notable for their low contents of manganese. Mines are mostly worked near rivers, and are open workings, or have shafts from 130 to 200 feet deep. About 550 mines with an annual production of a million tons are at work. Much of the ore is calcined, requiring 200 cubic feet of wood for 10 tons of ore; charcoal is seldom used for this purpose. The district furnishes half the total pig iron production of Russia. Some of the furnaces on the tributaries of the Volga import mazut or petroleum residues for heating purposes to avoid the cost of transporting wood. Limestone containing 4 per cent. of silica is used as flux to the extent of 10 to 15 per cent. of the charge. The slag is acid and brittle. Of the total production of 600,000 tons in 1895, 10 per cent. was made in Government works and the rest in private works. Over 100 blast-furnaces with 90 blowing-engines and 85 calcining kilns are now in operation.

**Iron Manufacture in India.**—J. Head\* has reported that it is not at present practicable to conduct an iron industry at or near Salem upon the methods employed in Styria and certain districts in America where charcoal is employed. The opinion is also expressed that it will not pay to export the Salem ore from Madras, nor to use Singareni coal for smelting the ore either at Madras or Salem. The report deals fully with the costs, supply of ore and charcoal, and other incidental matters. On the question of costs some objections have been taken by the Indian Board of Revenue, but the author's contentions are upheld in a recently published article dealing with these reports.

**Early Blast-Furnaces in the United States.**—Between 1820 and 1850 there were 23 blast-furnaces built in Venango County, Pennsylvania, the last one of which went out of blast about 1860. Hard ore and bog ore were smelted with limestone as flux and charcoal as fuel. The furnaces were usually built as truncated pyramids, 20 feet square at the base and 25 feet high, but a few were circular, one being 30 feet at the base and 36 feet in height. Wooden blowing-tubs were used, and a few of the later furnaces had hot-blast stoves.†

\* *Fort St. George Gazette*, December 15, 1896; *Indian Engineering*, vol. xxi. pp. 213-216.

† *American Manufacturer*, vol. lx. p. 296.

J. Whitehead \* states that soon after 1667 bog iron ore was discovered with 40 per cent. of iron near Tinton Falls, in New Jersey, and furnaces and other works were built. In 1676 these attained considerable magnitude, and were exempted from taxation to encourage the industry. The last mention of these works is in 1714, but now the ruins have disappeared.

**Anthracite Pig Iron Industry.**—E. Roberts † gives information on some points of the anthracite pig iron industry, and remarks relative to the costs and yields of actual workings at Yniscedwyn and in America.

**Iron-Making in Alabama.**—A monograph on iron-making in Alabama, by W. B. Phillips, has been published by the Geological Survey of that State, and contains a general description of the ores, fluxes, and fuels used, together with some particulars of the manufacture. The ores used are the soft and hard limey haematises and the brown ores in varying proportions. The use of the crushed hard ore is rapidly extending, and the particulars of a large number of furnace burdens are given to show the proportions and kinds of ore, flux, and fuel used. The great difficulty at present is the very variable quality of the ores. Some charcoal iron is still made in the district. A number of statistical details are given, and also reprints of papers from the Proceedings of various societies on grading pig iron and other matters.

C. A. Meissner ‡ gives some notes on the Southern iron industry, with a few remarks on that in Nova Scotia. The cheapness of iron in Alabama is ascribed to the abundance of suitable ore, to the cheapness of negro labour, which apparently is derived more from a vigorous application of truck methods than from a low rate of wages, and also to abundant use of prison labour.

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## II.—CHEMICAL COMPOSITION OF PIG IRON.

**The Constitution of Pig Iron.**—In a monograph on the present state of the pig iron industry in France, A. Pourcel § deals at length with the constitution and properties of cast iron. At one time it was

\* *New York Times*, through the *Engineering and Mining Journal*, vol. lxiii. p. 260.

† *Iron and Coal Trades Review*, vol. liii. pp. 668-669.

‡ *Canadian Mining Review*, vol. xvi. No. 1, pp. 12-15.

§ *Revue Générale des Sciences*, 1896, pp. 465-475, 510-543.

concluded that the maximum carbon content was between 4·10 and 4·60 per cent., but H. Moissan showed that by using the voltaic arc carbon could be dissolved in amounts proportional to the temperature up to 6 or 8 per cent. or more. Melted iron is therefore not a definite compound, but a solution of iron and carbon. In practice cast iron contains many other bodies, as is shown by the following very complete analysis of one sample :—

	Per Cent.
Carbon . . . . .	2·257
Silicon . . . . .	3·265
Phosphorus . . . . .	0·459
Sulphur . . . . .	0·036
Manganese . . . . .	0·388
Aluminium . . . . .	0·028
Chromium . . . . .	0·027
Vanadium . . . . .	0·012
Copper . . . . .	0·009
Nickel and cobalt . . . . .	0·035
Arsenic . . . . .	0·015
Antimony . . . . .	0·011
Calcium . . . . .	0·072
Magnesium . . . . .	0·100
Titanium . . . . .	0·025

Besides which, traces of the alkalies and alkaline earths may occur, but in general the essential elements are iron, carbon, and silicon, with variable amounts of manganese, phosphorus, and sulphur. After briefly giving the difference between the two especially marked classes of white and grey iron, the author proceeds to discuss the state in which the carbon exists. When white iron is attacked by dilute nitric acid, part of the carbon escapes as a gas, and part is left in a brown flocculent residue, which dissolves on heating and gives a brown solution. So-called combined carbon exists in two forms; one is dissolved as hardening carbon spread uniformly through the mass, as in steel, and gasifies on solution, and the other is a definite compound given by Abel and others as probably being  $\text{Fe}_3\text{C}$ . This is termed normal carbide carbon by Ledebur. Certain white irons, when dissolved in warm nitric acid, show in addition, especially after prolonged reheating, a black residue. This is called graphitic temper carbon by Ledebur, and differs from graphitic carbon in that it forms a hydrocarbon when heated in a current of pure dry hydrogen. Graphite itself forms the fourth variety of carbon, and is mostly developed in high carbon irons slowly solidified. The physical and mechanical properties of cast iron depend not only on the percentage of the total carbon, but also on the state in which it occurs. Thus the density of grey iron is always less,

than white iron containing the same percentage of carbon, but its melting-point is over 100° C. higher. The melting-point of pure iron, given by Osmond as a little above 1500° C., is lowered in proportion to the carbon present, and the most fusible of two kinds with equal carbon is that in which combined carbon preponderates. Graphitic carbon is liberated on solidification, and requires heat to redissolve it.

The form of the carbon depends not only on the temperature, but also on the other substances present—chiefly on the silicon, phosphorus, sulphur, and manganese. Silicon, though it possesses chemical properties similar to carbon, does not have the same effect on iron. It evinces its presence by increasing the graphitic carbon at the expense of the combined carbon, especially the hardening carbon, of which it often removes all trace. Silicon appears to dissolve in iron in all proportions, but it never separates out like graphite. It behaves towards iron as a more powerful element, and this explains its action on the carbon. When as much as 4 per cent., or even 3½ per cent., is present, the iron cannot be chilled. It diminishes the resistance of iron to shock, tensile and crushing tests, only with high proportions, such as 12 to 16 per cent. With low carbon the metal is hard, and will resist sudden stress. It may therefore be supposed that in graphitic silicon iron the weakness is produced by the large facets, which adhere to each other but feebly.

Phosphorus is found in all cast iron, and its reduction does not depend directly on the temperature, like silicon. The relative ease of formation of phosphoric irons allows the production of white very fluid irons with small percentages of carbon. On the other hand, it does not prevent the separation of graphite. The physical characteristics of phosphoric irons are their fluidity, which often facilitates casting, and the weakness of the iron increasing with the percentage present. These properties cannot be attributed to the effect on the carbon, but must be referred to the condition of the phosphorus itself in the metal. Osmond and Werth, by Weyl's electrolytic method, have apparently isolated a phospho-carbide of iron from white iron, and this body appears to be concentrated in the cementite. In grey iron phosphorus is only partly combined with the normal carbide, and the rest is diffused very unequally through the mass as some definite compound, possibly  $\text{Fe}_3\text{P}$ , which has not been isolated.

Sulphur acts in a contrary way to silicon, and tends to maintain the carbon in solution as hardening carbon or carbide carbon. It is not proved that sulphur lowers the saturation-point of carbon in iron, or, in

other words, that it favours the production of white iron low in carbon. Possibly it may be explained by the fact that a more sulphurous carburised iron can be formed at a lower temperature than one with less sulphur. In consequence, as with phosphorus, a lower temperature necessarily implies a lower content of carbon. This also occurs with phosphorus, but the latter renders low carbon iron more fluid, whilst sulphur gives a certain viscosity, doubtless because iron sulphur compounds are endothermic instead of being exothermic, like the phosphorus compounds. Karsten has given one experiment to show that certain proportions of sulphur raise the saturation-point for carbon. As regards physical properties, sulphur in certain cases, and within certain limits, improves iron by giving a closer, more homogeneous and regular grain, on account of its action in diminishing graphite. Thus iron at Finspong, in Sweden, containing 0·15 to 0·20 of sulphur, traces of phosphorus, and less than 1 per cent. of silicon, is strong enough to be used for cannon. Sulphur is distributed very irregularly in large masses of metal.

Manganese maintains the carbon partly or wholly in the combined state as hardening and carbide carbon. It also raises the saturation-point, but this is readily explained. Manganese alloys in all proportions with iron as do sulphur and phosphorus, but, unlike them, it does not materially affect the melting-point, so that when melted with an excess of carbon the iron dissolves it in proportion to the average temperature. On the other hand, as oxides of manganese are difficult to reduce, iron manganese carbon compounds are only formed under reducing conditions with an excess of fuel at high temperatures ; that is, when circumstances tend to increase the carbon saturation. Manganese, like iron, in combining with carbon, gives compounds that are decidedly exothermic, formed with a large disengagement of heat. This explains the increase of carbon as the manganese increases, even up to 7 per cent. in the combined form. In the hard and brittle rich manganiferous irons, the hardening carbon, although high, is lower than the carbide carbon, and in the normal carbide manganese is substituted for the iron. In most commercial iron, manganese is low (from 0·15 to 0·80), as iron ores with 2 to 4 per cent. of manganese are rare. From 1·50 per cent. and upwards this element begins to make itself felt in counterbalancing the effect of silicon. From 1·0 to 1·5 per cent. seems to increase the strength by fixing part of the carbon in the combined state, perhaps as hardening carbon. Manganese shows the least tendency to segregation of all the elements. Up to a certain point it

raises the melting-point, and it is to be noted that irons rich in manganese melt at a lower point than their temperatures of formation.

A. J. Rossi \* gives a translation of that part of Pourcel's paper relating to carbon and the other elements.

L. Olivier† discusses the part played by science in the pig iron industry, and shows how the chemist is called upon to analyse the fuel, flux, and ore, and the slag and iron produced. The education of the chemist and the scientific manager at various French and other schools is also described.

**The Grading of Pig Iron.**—The fourth section of a long account by A. Pourcel ‡ of the present state of the pig iron industry in France is devoted to the grading of pig iron. According to their fracture they are divided into seven classes, ranging from white through mottled to very grey. In practical use there are two classes, forge and foundry pig iron, besides special iron, such as ferro-manganese. In foundry iron extraneous substances are only regarded in view of their influence on mechanical properties, but in forge iron the effect on the conversion into steel is considered. Phosphorus, for example, is a heat-giving element in the basic process, but is inadmissible in the acid process. In foundry iron it increases fluidity but decreases strength, so that when it is below 0·20 to 0·30, strong iron is obtained. Foundry irons include the four or five grades of grey iron, but sometimes mottled iron is included, being used for cannon at Finspong and for rolls. Graphite being the essential element of foundry iron, the silicon which liberates it is indispensable. Phosphorus may be present from 0·20 to 1·50 per cent., and manganese as it counteracts silicon should not exceed 0·20 to 0·40. Forge iron may be grey or white, and may contain very variable amounts of impurities. Sulphur is not tolerated in either kind beyond 0·10 to 0·15 per cent. Chemical composition fixes the value of forge iron, but not of foundry iron, though many investigators have dealt with empirical rules governing their relation. Microscopic research may also help to elucidate these points. The author then gives a number of analyses of foundry iron of all qualities, and also deals with the kinds of iron used for puddling and for acid and basic steel-making. On the Continent white iron is used containing—

Carbon.	Silicon.	Phosphorus.	Sulphur.	Manganese.
2·50 to 3·00	0·20 to 0·40	1·60 to 1·80	0·50 to 0·25	0·0 to traces

\* *Iron Age*, vol. lviii. pp. 1301-1302.

† *Revue Générale des Sciences*, 1896, pp. 539-543.

‡ *Ibid.*, pp. 473-475.

Basic iron generally varies within the following limits:—

Carbon.	Phosphorus.	Manganese.	Sulphur.	Silicon.
3·20 to 3·40	1·80 to 2·25	1·60 to 2·00	0·07 to 0·05	0·06 to 0·04

According to W. H. Brannon,\* eleven grades of pig iron are now recognised in Alabama, these being two silvery, two soft, four foundry, grey forge, mottled and white. The appearance of these and the silicon contents are given.

W. B. Phillips † also deals with grading, and shows that the grade as shown by the fracture and by the silicon contents, are often far from agreement. Some agreement as to the combined effect on the grade of both silicon and carbon is therefore necessary, and the following is suggested :—

	Silicon.	Combined Carbon.	Sulphur.
Silvery irons . . . . .	5 to 6	0·10 to 0·30	0·01 to 0·04
Soft irons . . . . .	3 „ 5	0·20 „ 0·60	0·01 „ 0·06
Foundry irons . . . . .	2 „ 3	0·30 „ 0·90	0·01 „ 0·07
Grey forge . . . . .	1 „ 2	0·40 „ 1·25	0·04 „ 0·09
Mottled . . . . .	0·6 „ 1	0·50 „ 1·80	0·06 „ 0·11
White . . . . .	0·1 „ 0·6	1·00 „ 2·60	0·08 „ 0·30

**Foundry Pig Iron.**—O. Simmersbach ‡ shows by analytical results how greatly one may be deceived in judging by the size of the grain the quality of foundry pig iron. This is shown by the following results :—

Pig Iron.	Silicon.	Grain.	Pig Iron.	Silicon.	Grain.
No.	Per Cent.		No.	Per Cent.	
1.	{ 2·07 2·01	Very coarse. Almost fine.	6.	{ 1·70 1·96	Very coarse. Somewhat coarse.
2.	{ 1·94 1·72	Somewhat coarse. Coarse.	7.	{ 1·86 1·83	Fine. Coarse.
3.	{ 1·82 2·43	Both somewhat coarse.	8.	{ 2·51 1·85	Fine. Somewhat coarse.
4.	{ 1·59 1·67	Coarse. Fine.	9.	{ 2·17 1·85	Fine. Coarse.
5.	{ 1·40 2·06	Both coarse.	10.	{ 1·94 3·06	Both coarse.

No. 11 was coarse-grained with 2·00 per cent. of silicon and fine-grained with 3·13 per cent.

\* *Proceedings of the Alabama Industrial Society*, vol. vi. pp. 11-14.

† *Ibid.*, pp. 15-23.

‡ *Correspondenz No. 117 des Vereins Deutscher Eisengießereien*.

How greatly the silicon influences the separation of graphite from pig iron is shown by the following results :—

Pig Iron.	Silicon.	Total Carbon.	Percentage of Carbon as	
			Graphite.	Combined Carbon.
No.	Per Cent.	Per Cent.		
1.	1·65	3·59	72·2	27·8
2.	1·74	3·98	84·2	15·8
3.	1·76	4·05	84·5	15·5
4.	1·80	3·61	88·9	11·1
5.	1·87	3·75	89·3	10·7
6.	1·91	4·04	90·1	9·9
7.	1·95	4·03	90·6	9·4
8.	2·00	3·78	90·7	9·3
9.	2·03	3·81	90·8	9·2
10.	2·10	3·40	91·8	8·2
11.	2·26	3·76	92·3	7·7
12.	2·41	3·89	92·8	7·2
13.	2·87	3·81	93·0	7·0
14.	3·01	3·67	93·5	6·5

The author consequently concludes that the value of foundry pig iron is not to be estimated from its appearance, but chiefly by its chemical composition, and especially by the percentage of silicon it contains. He suggests that foundry pig iron should be classified as follows :— No. I. with a high percentage of silicon; III. with an average percentage of silicon; V. with low silicon. No. II. might be No. I. with less than 3·5 per cent. of carbon, or No. III. with about 1 per cent. of manganese, and IV. might similarly be III. with less than 3·5 of carbon, or V. with some 1 per cent. of manganese. Pig iron very high in silicon, and containing in addition from 1 to 1·5 per cent. of manganese and a high percentage of carbon, might be called Ia.

**Forge Pig Iron.**—According to Jacobsson,\* in a first-class forge pig iron, phosphorus should be from 0·01 to 0·02, and silicon at the most 0·3 to 0·4. It must be perfectly free from sulphur and manganese, and must not contain any slag-forming constituents in larger quantity than is necessary for the production of sufficient slag in the hearth, or fining without rendering the addition of other slag a necessity. In fracture it must be half white, half grey, or, better, two-thirds white and one-third grey, when the grey fracture must possess a distinctly marked crystalline texture. The surface must be free from slag,

\* *Wermåndská Annaler, Berg- und Hüttenmännische Zeitung*, vol. iv. p. 26.

sand, and other impurities. The author also describes how it should behave under treatment, and also refers to the character of the resulting malleable iron. Another kind of pig iron frequently treated in the Lancashire hearth contains from 0·5 to 0·8 per cent. of silicon, 0·03 to 0·1 of phosphorus, 0·15 to 0·3 of manganese, little or no sulphur, and such a large quantity generally of slag-forming constituents, that slag is actually formed in so considerable a quantity during the subsequent treatment of the metal as to interfere with the process, and to tend to spoil the character of the resulting metal. The fracture of this pig iron is very like that of the one previously mentioned, but occasionally the grey portion is in excess, and shows a smaller or more velvet-like grain, and ash-grey colour. Such a pig iron is much more difficult and unsatisfactory to treat than the one first mentioned, and indeed it would seem that it is to the treatment of such a pig iron as this that the complaints as to the high cost of treatment in the hearths are mainly due.

**Sulphur in Pig Iron.**—G. R. Johnson \* suggests that the rough face on the lower or less graphitic grades of pig iron is due to the giving off of occluded gases, particularly sulphurous oxide, instead of to the absence of silicon, to which it is often ascribed. A number of analyses are given to show that when the iron chilled promptly the sulphur contents were higher. Some tests were made, but without much result to prove this. The tables of analyses deal with forty-three samples, of which nine were taken in three lines across the broken face of each pig, and they show the distribution of this element.

### III.—BLAST-FURNACE SLAG.

**Slag Cement.**—At Vitry-le-François, Lorraine, slag from the Pont-à-Mousson furnaces is used for making slag cement. The slag has approximately the composition—

Alumina.	Silica.	Lime.	Oxides of Iron, Magnesia, &c.
22	32	42	4

Slag containing much iron is rejected, and also the first and last portions from each tapping. To granulate the slag a strong jet of water

\* *Transactions of the American Institute of Mining Engineers*, 1897, Chicago meeting (advance proof).

is brought to bear on the stream of slag as it flows from the furnace. The sand is collected and freed from its 9 per cent. of water left after drainage by spreading it on flat iron trays, passed slowly through a heating chamber at 600° to 700° C. After sifting it is very finely ground, bolted, and mixed very carefully with accurately weighed amounts of lime, in revolving cylinders containing cast iron balls. Bricks are made by mixing six parts of lime with 25 to 30 parts by measure of the slag sand. Pipes are made from river sand and cement mixed into a mortar and rammed into steel moulds. After drying for three days, they are immersed in water for a day, and then stored for three months.\*

**Slag Bricks.**—Slag bricks, weighing 10½ lbs., strong enough to serve for all building purposes, and taking the mortar well, are made at the Karl-Emil Ironworks, Königinhof, Bohemia,† from a slag containing 25·8 to 27 per cent. of silica; 1·5 to 1·7 of ferrous oxide; 17·3 to 19·3 of alumina; 51·5 of lime; 0·4 to 2·5 of magnesia; and 1·3 to 1·8 per cent. of sulphur, yielded by impure oolitic iron ore smelted with coke. On leaving the taphole, the slag, containing but little ferrous oxide and no manganese protoxide, is granulated into sand of a light grey colour, which is led into a cylindrical receptacle, where it is mixed with the cement necessary for giving cohesion. This cement is made from slaked lime, allowed to remain exposed to the atmosphere, and then mixed with fine slag sand. The bricks, which must be left to harden before being removed, show a resistance to crushing strain of 256 lbs. per square inch. The finished blocks, which contain silica 26½, alumina 17, and lime 52 per cent., will stand a pressure of nearly five tons.

#### IV.—*FOUNDRY PRACTICE.*

**Cupola Practice.**—In response to a circular letter issued by an American journal,‡ a number of replies have been received on various points of cupola practice. Amongst the points brought out are that more continuous melting is a desideratum, but that hot-blast for

\* *Nouvelles Annales de la Construction*, through the *Engineering News*, vol. xxxvii. p. 2.

† *Berg- und Hüttenmännische Zeitung*, vol. lv. pp. 342-344.

‡ *Iron Trade Review*, vol. xxix. No. 45, p. 9; No. 46, p. 11; No. 47, p. 8; No. 48, p. 8.

cupolas is scarcely practicable at present, owing to the discontinuity of running. The centre-blast is highly spoken of in some quarters, and others again recommend that the tuyeres should be placed low, and the charging hole higher than is now the practice. E. Kirk mentions two experiments where the hot-blast was a failure; in one a separate pipe-stove, and in the other pipes in the stack were used, but broke on account of alternations of heating and cooling.

A short discussion has taken place\* on the advantage of coal and coke for cupola-melting. As a rule, coke is used, but a few foundrymen use coal alone in the cupola, and others use it as a bed, afterwards charging coke with the iron. In some cases the coal appears to deteriorate the quality of the iron. The cost of castings was also dealt with.

At a recent meeting of the Western Foundrymen's Association,† a discussion took place on the question of what is the proper amount of air and its pressure to melt iron in a cupola, and what are the effects of too much and too little air. The ordinary practice assumes 2500 lbs. of air for 2000 lbs. of iron melted, assuming 8 ounces of blast-pressure and a melt of 7 lbs. of iron per pound of coke. Excessive blast causes faster melting, but it burns out the softener, and produces colder iron. On the other hand, other melters use up to 15 or 16 ounces pressure, and find cold iron with diminished blast. With soft coke lower pressures are desirable.

Several members ‡ had found that central-blast cupolas were always getting out of order, but some stated that good results were obtained.

E. Grindrod § gives some practical hints on running a cupola, urging the necessity of greater attention to uniformity in charging and melting.

L. C. Jewett || gives a racy account of the methods he has seen employed for stopping leaks in the bottoms of foundry cupolas, and describes the methods of making the bottom so as to stand properly by treading in slightly damp sand.

It is pointed out by Bolze ¶ that the cupola is the type of furnace in general use in the remelting of pig iron. The cylindrical furnaces

\* *Foundrymen's Association*, through the *Iron Age*, vol. lviii. p. 719.

† *Iron Age*, vol. lix. No. 8, pp. 11-12.

‡ *Ibid.*, vol. lviii. p. 719.

§ *The Foundry*, September 1896, through the *Engineering Magazine*, vol. xii. pp. 518-520.

|| *American Machinist*, through the *Iron Trade Review*, vol. xxix. No. 47, p. 9.

¶ *Dingler's Polytechnisches Journal*; *Berg- und Hüttenmännische Zeitung*, vol. lvi. pp. 19-20, with seven illustrations.

which are now almost solely used, differ from each other mainly in the way the blast is introduced, the various modifications nearly all turning on an attempt to reduce the quantity of coal consumed in the remelting of the pig iron. An important variation, however, from the ordinary type is the Krigar cupola, which is provided with a fore-hearth—a collecting chamber—between the cupola proper and the tap-hole. The Herzberg, Hann-West, and Hibler's cupolas are described, and illustrations are also shown of the three latter. The Bolze cupola is also described and illustrated.

**Foundry Plant.**—Illustrations and a plan have been published \* of a foundry plant recently built at Lorain, Ohio, to make ingot moulds, rolls, and heavy castings up to 75,000 lbs. The main building is 154 by 160 feet. The central roof trusses, 61 feet in span, rest on steel columns, which also carry the rails for a 35-ton overhead electric crane. One side used for light castings is commanded by a 5-ton crane. The other side contains the core ovens, a cupola, and two 15-ton reverberatory furnaces. The casting-pit for the latter is situated adjacent to them under the central span, and is 12 feet in diameter by 12½ feet in depth.

A plan and some twenty illustrations have been published † of the recently completed works of a foundry at Bristol, Connecticut. Narrow-gauge tram-lines and electric transmission of power are freely employed. The foundry building itself is 532½ by 112½ feet, with a roof from 18 to 30 feet from the floor. Five cupolas have been built, but there is room for three more. Lavatory arrangements for the men and air-heating appliances for warming the building are provided on an extensive scale, and the works are so laid out that the material flows steadily from the receiving to the shipping ends.

**Regulating Foundry Mixtures.**—According to Thomas D. West, ‡ heavy founding gives the best opportunities for obtaining knowledge of the manner in which the various metalloids affect the carbon in giving characteristic qualities and in changing the grade of iron, as in heavy founding castings of all grades are demanded. Then, again, in order to obtain accurate information, actual practice must be dealt with, for physical conditions in founding can often affect the character

\* *Iron Trade Review*, vol. xxix. No. 46, pp. 12-18; *Iron Age*, vol. lviii. pp. 768-769.

† *Iron Age*, vol. lix. No. 7, pp. 1-9.

‡ Paper read before the Pittsburgh Foundrymen's Association, through the *Iron and Steel Trades Journal*, vol. Ix. p. 270.

of iron or the condition of its carbon as much as changes in its chemical composition. Tests of iron from a crucible, &c., are of little value in advancing practical knowledge, and have only created confusion of methods and ideas as to the effects of metalloids. Some advise regulating the mixture, or changing the "grade" of the iron, by means of alterations in the percentage of silicon, manganese, or phosphorus. It is impossible to obtain uniform grades of iron from like mixtures of ore, fuel, and limestone; and it would seem that there are metalloids that cannot be controlled. Analyses prove that silicon and sulphur are the metalloids wholly responsible for creating the difference in grades of iron, coming from similar mixtures of ore, fuel, and limestone in smelting, from the fact that the total carbon, manganese, and phosphorus generally remain practically the same, one cast after another.

G. R. Johnson \* takes exception to some of these statements, and gives analyses to show that successive castings from a cupola can be made very nearly alike. Manganese is not constant, but varies with the heat, and the statements regarding the effects of sulphur and silicon on the grade are also objected to.

W. B. Phillips † agrees with the author in some respects, but thinks that combined carbon must be considered in the grading, and that therefore grading by analysis is the only method possible.

**Steel Cores for Casting.**—G. L. Roby ‡ advocates the use of steel cores instead of sand cores for many purposes in castings. They can, for instance, be used with advantage in casting wheels and other work where a finished hole has to be left in the hub or elsewhere, and also where coarse threads have to be made in the casting. Vertical steel cores should not exceed half the diameter, and horizontal cores one-third of the diameter of the adjacent part of the casting. To permit of their withdrawal and to avoid chilling, the cores are coated with a special refractory composition by dipping, but the nature of the material is not given.

**Drying Cores.**—A committee appointed by the Foundrymen's Association § to consider the subject of core-drying have presented an interim report, and think that a temperature of 350° to 400° F. is the best for drying cores thoroughly. Larger cores will take more time in

\* *Iron Trade Review*, vol. xxx. No. 6, p. 12.

† *Ibid.*, No. 9, p. 11.

‡ *Age of Steel*, vol. lxxxi. No. 13, pp. 16-18.

§ *Iron Trade Review*, vol. xxix. No. 52, pp. 13-14; *Iron Age*, vol. lviii. p. 1257.

proportion to their size, but both the temperature and all other details depend largely on the kind and material of the cores. Some details of ovens are given.

**Casting Wheels.**—In laying out wheel-foundry floors, either the chillers are arranged in a circle with a jib-crane in the centre, or they are placed in parallel rows, each row commanded by a light travelling crane or rope-driven carrier. An annealing pit is placed at the end of each row. The latter system is more economical in space, but the former allows of more light from overhead. Various forms of cranes are also mentioned.\*

**Casting Chilled Rolls.**—In order to produce a uniform depth of chill in cast rolls, it is necessary that the roll should remain central in the mould as it cools and contracts. For ensuring this a number of grooves are made on the interior surface of the vertical mould, and these grooves are bevelled on the lower edge. Corresponding ridges are therefore formed on the casting, and the weight of the roll as it contracts causes it to slip down uniformly, and thereby maintain its concentric position. The grooves for the largest rolls are only made  $\frac{3}{16}$ -inch deep, so that the roll can be lifted out of the mould, and the ridges are small, so that they can be turned off easily. The results obtained are stated to be very satisfactory.†

**The History of Cast Iron Pipe.**—J. Garrett ‡ deals with the history of cast iron pipes, and states that in 1685 they were used for the water service at Versailles, and that in 1682 iron pipes were used for water at Marli, near Paris.

In 1582 Peter Maurice erected pumps at London Bridge—pumps with cast iron cylinders. In 1835 it was estimated that over 1000 miles of iron pipe were laid in London for water, the first iron pipes having been laid in 1746. In America the first cast iron pipes for the water service of Philadelphia were made as direct castings from a blast-furnace smelting bog iron ores. These pipes were cast on their sides.

**Cast Iron Steam-Pipes.**—It has been pointed out that steam-pipes made of cast iron should only be cast on end, so as to avoid differences

\* *Railway Review*, through the *Iron Trade Review*, vol. xxix. No. 47, pp. 12-14.

† *Iron Trade Review*, vol. xxx. No. 8, pp. 8-10.

‡ Paper read before the New England Waterworks Association, through the *Bulletin of the American Iron and Steel Association*, vol. xxxi. p. 50.

of thickness, such as occur from the bending of the core. One firm, in describing the manufacture, states that the mould is made of dry sand, and the core of a stiff core-bar covered with hay-rope and two coatings of loam, dried and covered with facing. Every pipe now cast in the best foundries is now tested under 250 to 400 lbs. hydraulic pressure, and rapped with a hammer while under pressure.\*

**Contraction of Castings.**—F. Schuman† considers the contraction and deformation of iron castings in cooling from the fluid to the solid state. Deformation may be overcome by providing counter-deformation in the pattern, or by the addition of readily removable auxiliary parts. Generally the section should be so subdivided or designed that the ratio of the cooling surface to the prism is alike around the centre of gravity of the prism. For complex castings the design should be such that there is the least difference in the rate of cooling, or ratios of the different members. Sudden changes of form cause severe initial stresses, if not fracture, and should be rigidly avoided. Imperfectly proportioned flanges, ribs, or gussets added to the main body of a casting, for either the purpose of increasing the strength or connections, may be a source of weakness. Hollow cylindrical columns, although cast of even thickness and left in the mould until cold, may become crooked by the unequal cooling due to air currents after the core is removed, so the ends should be immediately stopped with sand. Greater attention to the laws of cooling, correct forms and proportions of castings, will result in increased strength and economy, besides the avoidance of crooked castings and mysterious breakdowns.

A large and complex casting weighing 48,300 lbs. for a pump-chamber is illustrated.‡

**Cleaning Castings.**—An illustration has appeared § of an appliance for cleaning castings. It practically consists of a wire brush revolving at about 2200 revolutions per minute, and the special feature is that the wire bristles are loosely pivoted on the hub, so that they fly out under centrifugal action.

\* *Iron Trade Review*, vol. xxix. No. 50, p. 7.

† Paper read before the American Society of Mechanical Engineers, through the *American Manufacturer*, vol. lix. p. 909; *Industries and Iron*, vol. xxii. pp. 135.

‡ *Iron Age*, vol. lvi. pp. 1185-1186.

§ *Ibid.*, pp. 816-817.

**Stove-Plate Scrap.**—C. Johnson \* gives the analysis made from a cast of five tons of stove-plate scrap as follows:—

Combined Carbon.	Manganese.	Phosphorus.	Silicon.	Sulphur.
0·96	0·21	0·938	2·86	0·123

Such iron may be used with high silicon iron low in phosphorus in preference to machinery scrap, as the elements are more uniform.

**Moulding.**—S. Groves† describes the application of moulding-machines to spur-wheels and other gearing. For worms, the pattern is screwed out of the mould by the use of a guide. For small spur-wheels a pattern made in one piece is used. For medium-sized wheels up to six feet in diameter, the mould is made on a revolving table, but larger wheels have to be made on the floor with a central arm-machine. Coarser sand is used than for smaller wheels, and with large teeth it is necessary to vent each tooth space by leaving an oblong hole and filling it with coke. The mould should be dried by gas jets from a ring 12 inches less in diameter. A great improvement consists in the use of hollow coke-filled green sand for dry sand arm cores, as the shrinkage is facilitated. Strong dry sand covering cores are used instead of iron or wooden copes. Close-grained metal poured hot should be employed. The author's moulding-machine is also described.‡

A series of articles by J. Horner§ on the subject of moulding wheels has also been published.

G. O. Vair|| describes the methods of moulding press rolls for paper-mills in dry sand. The core consists of a perforated pipe with the ends coated with loam and the central part with sand. The mould is made with sand in a vertical core-box, which has a stud at the bottom for centering the core.

T. Addison¶ advises the mixture of black or used sand with new sand when making facing sand for green sand moulds, and specifies the proportions of these materials with coal and flour as used for compound cylinder castings weighing 4 tons. Clay water is recommended as a wash for dry sand and loam moulds.

\* *The Foundry*, through the *American Manufacturer*, vol. ix. pp. 297-298.

† *Iron Trade Review*, vol. xxx. No. 8, pp. 12-13.

‡ *Ibid.*, No. 2, pp. 9-10.

§ *Engineering*, vol. lxiii. pp. 65-67, 125-127, 195-196, 333-336, 395-399, 429-431, 563-564, 631-632.

|| *Machinery*, through the *Iron and Coal Trades Review*, vol. liv. p. 46.

¶ *Iron Moulder's Journal*, through the *Iron Trade Review*, vol. xxix. No. 42, p. 15.

Illustrations have appeared \* of the Bryant moulding-machine, which is adapted for moderate-sized foundry-work. It consists of a horizontal revolving table carrying a number of flasks capable of being raised and lowered. A horizontally-swinging frame carries the ramming hammers, sand-receiving mechanism and other operating parts.

Illustrations have also been published † of the Ryan sand-core moulding-machine for making any cores that can be produced in two half boxes. The core-box is fed forwards on a horizontal slide-table under the sand-feeding hopper, then under a brush to be levelled, then under the vent-press, where the sand is pressed and vented, and next under a flour-distributor.

T. A. Haigh ‡ gives some notes on the gates used in moulds for casting various kinds of work, with special reference to their power of keeping dirt out of the casting.

**Foundry Costs.**—Four anonymous papers on foundry costs were presented at a recent meeting of the New England Foundrymen's Association. § In one of these the points required are given as the cost per pound of each class of work, or of each separate piece of work, and the estimation of cost for new work. The cost of material can most readily be found from the results of a year's work, if careful observations are taken of the weights of iron used, cast and wasted, but the items of labour and other expense are not so readily determined. These costs, however, are considered under the head of fixed charges for plant, &c., incidental expenses and supplies.

**Foundry Apprentices.**—A committee appointed by the Western Foundrymen's Association || has issued their final report on apprentices, classifying them under three divisions—general machinery moulders, stove-plate and agricultural instrument moulders, and bench and brass-moulders, with periods of four, three, and two years' apprenticeship respectively. Wages and duties are described, and a discussion on the report ensued.

\* *Iron Age*, vol. lviii. pp. 905-907; *Engineering News*, vol. xxxvii. pp. 110-111.

† *Iron Trade Review*, vol. xxx. No. 3, p. 8.

‡ *Iron Moulder's Journal*, through the *Iron Trade Review*, vol. xxx. No. 11, pp. 12-13.

§ *Iron Trade Review*, vol. xxx. No. 3, p. 10.

|| *Iron Age*, vol. lviii. pp. 812-813, 1006, 1256.

## PRODUCTION OF MALLEABLE IRON.

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**Steam-Hydraulic Presses in place of Shingling Hammers.—** B. Meyer \* refers to the decadence of the puddling industry, and to the more modern improvements introduced in connection with it. There is still a demand for malleable iron, and he refers to a case in which it was found necessary to erect a puddling plant although the works already possessed a steel plant. The difficulty had to be met that dwelling-houses were in the immediate vicinity, and the use of steam-hammers was therefore most objectionable. The best method of replacing these was carefully considered. At first it was thought the old crocodile press might prove useful, but it was felt that this would be a very backward step as far as progress was concerned. Then an arrangement in which an eccentrically arranged roll rotates inside a fixed drum—an arrangement in common use in the United States—was considered. The bloom is very badly pressed, though, in this way, and this bloom-mill was therefore not adopted. In this difficulty it occurred to the author that a hydraulic press might be used just as well in the puddling process as in others, and it was decided to make the experiment. He compares hammers and presses for use in puddling, and he considers that presses have the advantage. They cost less to erect, are more rapid in work, and the working costs are less. With regard to the quality of the metal obtained in this way, the author observes that it is usual to require for puddled iron of good quality a tensile strength not exceeding 24·1 tons per square inch, with 15 or 18 per cent. elongation. The average of fifteen tests of such metal, made with the use of the press instead of the hammer, showed a tensile strength of 24 tons, and an elongation of 23·73, whilst five samples specially puddled for "quality" gave on the average a tensile strength of 29·2 tons per square inch, with an elongation of 20·5 per cent.

\* *Stahl und Eisen*, vol. xvii. pp. 257-261, with one illustration.

**Use of Petroleum in Puddling Furnaces.**—J. Kowarsky\* describes and illustrates the application of petroleum as fuel for puddling furnaces. It has been found best in such methods of firing not to endeavour to fully subdivide the oil by the use of superheated steam outside the furnace, but to allow it to flow into the gasifying chamber by excess of pressure only, and there to gasify it by radiant heat, avoiding contact with air. As a general rule, he says, the use of petroleum can be considered commercially advisable whenever the price of its unit weight is equal to or less than that of 2·5 parts of coal. For work on a small scale, where petroleum motors can be used, the ratio may be 1 : 3·5 or even 1 : 4·5.

**Manufacture of Wrought Iron in Upper Silesia.**—F. G. Bremme † observes that in 1895 there were in operation in Upper Silesia 280 puddling furnaces and 138 welding furnaces at thirteen works. The process is relatively more employed in this district than in other iron districts, as the iron produced from the Upper Silesia ores is of good quality and has a free market. The forge pig iron made from the ores of the country alone, without admixture of foreign ores, is however usually higher in silicon than is desirable for the manufacture of puddled iron, and it is not an easy matter out of the native ores by themselves to produce a pig iron as low in silicon as the puddler would wish for. This forge pig iron shows a marked tendency to yield a fibrous iron of excellent quality; a good fine-grained iron can, however, also be produced from it. Pietzka puddling furnaces have been introduced at the Zawadski Works, and methods of coal-dust firing have also been adopted.

**An Ancient Iron Furnace.**—W. Grempler has described an old iron furnace which he considers dates back to the tenth century. It is discussed by H. Wedding.‡ It was found near Mönchmotschelitz, in Silesia. It is made of clay, and in section is not unlike a blast-furnace with exaggerated boshes. In the upper half, above these boshes, there is a tuyere hole on each side. Below the boshes it is contracted and is shaped into a horizontal pipe form, through which the slag was doubtless run out. The furnace as illustrated has a maximum height of 26½ inches and a maximum outside width of about

\* *Stahl und Eisen*, vol. xvi. pp. 915-917, with four illustrations.

† *Ibid.*, p. 761.

‡ *Ibid.*, p. 981, with three illustrations.

25½ inches. It contracts towards the top, where it is only a little over 18 inches wide in the clear. The blooms, however, which were made in this old-time process were very small.

**Ancient Wrought Iron Work.**—Drawings have been published \* of some ancient ornamental iron work exhibited in the Museum of Science and Art, Dublin. The examples described are of exceptional interest, both from an artistic and archaeological point of view.

Drawings have also been published † of some examples of wrought iron work in the South Kensington Museum, mostly of the seventeenth century. These serve to illustrate some of the decorative effect that may be obtained from the simple treatment of wrought iron in lines which express more or less the ductility of the metal, without any of the more elaborate effects of smith's work in conventional foliage and other such details.

\* *The Builder*, vol. lxxii. p. 37.

† *Ibid.*, p. 169.

## FORGE AND MILL MACHINERY.

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**The Bethlehem Plate-Mills.**—An account of these new plate-mills, illustrated by numerous elevations and plans of the mills, has recently been published,\* together with a plan of the additions to the works. The new part is 1150 feet long, making the total length 1900 feet, and the breadth ranges from about 110 feet upwards. The open-hearth plant consists of four 40-ton furnaces, of which one may probably be basic lined. They are served by twenty-nine large Siemens producers, and each has an 18-ton auxiliary hoist. Provision has been made for taking molten metal from the Bessemer plant to the charging platform. The casting-pit is controlled by a 75-ton overhead electric travelling crane, and an additional 100-ton crane is to command the whole plant. Ingots go to four pit furnaces, each capable of holding six ingots.

The 32-inch slabbing-mill is driven by two engines, one 46 by 60 inch, geared 5 to 7, driving the horizontal rolls, and the other, on the other side of the train, is 28 by 48 inch, and drives the vertical rolls. Both are hydraulic reversing; with steam at 100 lbs., they are rated at 6000 and 2240 horse-power. Aiken feed-tables are driven by two double 12 by 12 inch reversing engines. The vertical rolls are 20 inches, and the horizontal ones 32 inches diameter. The screws are driven by electromotors. The manipulator is hydraulic. A 25-ton electric crane takes the slabs to a hydraulic hot-shear, capable of dealing with a 20 by 48 inch slab, with tables driven by an 8 by 12 inch and an 8 by 8 inch double reversing engine. Three pit-heating furnaces are close to the shear. A rope-hauled truck takes the plates to the 34-inch plate-mill. This is three-high with a 20-inch middle roll, and the outside rolls 34 inches in diameter and 128 inches in width. It is driven by a 46 by 60 inch engine. The rolled plate is delivered to the shear by cooling tables 296 feet long, driven by two double 6 by 10 inch reversing engines.

\* *Iron Age*, vol. lix. No. 3, pp. 3-7.

A 26-inch universal mill is driven by a 42 by 60 inch reversing engine of 5000 horse-power. The 26-inch horizontal rolls are 6 feet wide, and the top-roll has a lift of 18 inches. Balance weights and electro-motors adjust the rolls. The two sets of vertical rolls are 16½ inches in diameter, oiled from the inside. The crane arrangements, boilers, and hydraulic plant are also briefly described. Two hydraulic mains, with water at 35 and 475 lbs. respectively, supply water-power.

**Flow in Rolling Steel.**—W. Cuthill \* discusses the flow in steel-rolling, in view of Tresca's experiments on the flow of solids and the propulsion of ships and other hydraulic analogies. In a water-nozzle the pressure varies as the square of the speed. High speed in rolling-mills requires much more power, which may be taken as the 1·6 power of the speed, as results show that piston pressure has to be raised 35 per cent. to increase the bar speed from 300 to 500 feet per minute. The size of the rolls are then dealt with, and the author concludes that large rolls are preferable if the analogy with water-nozzles of corresponding form is to be maintained. Heavier drafts are also recommended on the analogy of increased displacement in ships. Reduced speed, however, is considered as the chief factor in economy of power, and the heavier draft permits the out-turn to be maintained.

**Rolling-Mill Engines.**—Illustrations of a rolling-mill engine of 10,000 horse-power have recently been published.† The engine is reversing, and drives direct on to the mill. It has two 50-inch cylinders with 72-inch stroke.

**The Apollo Iron and Steel Works at Vandergrift, Pennsylvania.**—The converter-house is 1120 by 80 feet, the rolling-mill 800 by 140 feet, the annealing department 200 by 80 feet, and the boiler-house 255 by 45 feet, with twenty-four Cahall boilers, rated at 6000 horse-power. The engine-room is 250 by 40 feet, and contains two bar-mill engines of 1000 horse-power each, one blooming-mill engine of 2000 horse-power, and three tandem compound Bull engines of 300 horse-power each. These latter drive dynamos which furnish current to electro-motors used as follows:—Three 50 horse-power centrifugal pumps; two 35 horse-power pumps; four 20 horse-power

\* *Journal of the West of Scotland Iron and Steel Institute*, vol. iv. pp. 55-60, with one plate.

† *Iron Age*, vol. lviii. pp. 856-857.

shearing machines; one 45 horse-power motor for the machine-shop; three motors of 75, 50, and 30 horse-power for the live rollers and shearing machines in the bar-mill; three 25 horse-power and one 8 horse-power charging machines; and for driving one 25-ton, three 20-ton, and one 50-ton travelling cranes. The current is also used for lighting.\*

**Rolling Wire-Rod.**—The wire-rod mill of the Illinois Steel Company at Joliet, Illinois, during the second week of March made 3273 tons of No. 5 rods. The entire product was heated in two continuous heating furnaces, most of the billets being charged hot from the blooming-mill. The work was done in a twin mill, the roughing-mill being continuous, and the billets being finished in two mills of the ordinary Garrett type.†

**Shearing Machine.**—Illustrations have been published ‡ of a heavy double-angle shears capable of shearing 8 by 8 by 1 inch angles. Its special feature is that it is mounted on a turn-table 10 feet in diameter, so that it can be turned in any direction. Live and exhaust steam are carried by pipes through the base, so as to avoid overhead pipes.

**Electric Transmission of Power.**—W. Dixon § shows what great advances have been made in the adoption of electric transmission of power in works, and compares the excessive expenditure of power in belting and shafting and in steam transmission with the relative economy of electricity. Possibly, but not necessarily, with the exception of large cogging-mills in steelworks, there is no reason why, under existing conditions, electric motors should not be wholly employed and arranged to work in an efficient manner, consuming 30 to 40 lbs. of steam per horse-power hour for such time only as work is being done, as against the present method, which necessitates a more or less constant expenditure of three to five times this amount. Amongst other advantages are that large machines seldom in use may have separate motors, overhead shafting is unnecessary, machines may be fixed in any suitable place, and varying speeds may be obtained. After referring to costs, the author deals with the use of blast-furnace

\* *Iron Age*, vol. lviii. p. 720.

† *Iron Trade Review*, vol. xxx. No. 11, p. 7.

‡ *Iron Age*, vol. lviii. pp. 1299.

§ *Journal of the West of Scotland Iron and Steel Institute*, vol. iv. pp. 38-54, 61-70.

gases in gas-engines. At Wishaw an electric installation has been successfully driven by a gas-engine, using about 105 cubic feet of these gases per actual horse-power hour, and some figures are given to show what may be attained. Some discussion on the multiplication of small motors and the use of gas in gas-engines ensued.

**A Two-Hundred Foot Gantry Crane.**—For handling the material in the storage-yard, 400 by 800 feet area, of the Cambria Iron Company at Johnstown, Pennsylvania, several plans, such as stationary derricks, overhead travelling cranes, and tram-lines were considered, but it was finally decided to build two travelling gantry cranes, each of 200 feet span, so as to command the whole yard. These are described by J. W. Seaver,\* who points out the saving of space due to this construction. The span of the crane is built up of two Pratt type girders, placed so as to give it a triangular cross section, and its under surface is just over 21 feet above the ground. These main trusses are 18 feet deep at the centre and 9 feet at the ends, and are braced together above the track on which the trolley runs. Each leg of the crane is also in the form of an equilateral triangle, and rests on two trucks, spaced  $43\frac{3}{4}$  feet apart between their centres. The trucks each have four double-flanged 24-inch wheels, running on two rails of  $3\frac{1}{2}$  feet gauge. A 6-inch steel ball is arranged on the truck under the leg it supports, so as to give some play for expansion. The wheels on one truck on each side are geared together, and are driven from a main shaft extending across the span and driven by a 50 horse-power electro-motor in the centre. The trolley which travels on the runway beneath the span is of the ordinary crane type, and the hoisting is done by two twenty-five horse-power motors. The driver's cabin is attached. The speeds per minute are : Traverse of main bridge, 200 feet ; of trolley, 400 feet, and of hoist with full load, 20 feet. The end frames are arranged so that the trolley can be run from one crane to the other to transfer a load across the yard.

\* Paper read before the American Society of Mechanical Engineers, December 1896, through the *Iron Age*, vol. lviii. pp. 1188-1193, with illustrations.

## PRODUCTION OF STEEL.

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### *I.—THE CARBURISATION OF MALLEABLE IRON.*

**Chrome Steel**—According to E. Priwoznik\* and Peterson, the chrome steel which is made at Eibiswald, in Styria, has the composition—

Chromium.	Combined Carbon.	Silicon.	Phosphorus.	Sulphur.	Manganese.	Iron.
2·15	4·03	0·26	0·06	0·01	1·45	92·00

A ferrochrome also produced contains—

Chromium.	Iron.
44·5	48·2

The chromium was determined by the Peterson method.

**Austrian Steel**—According to E. Priwoznik,† the following are analyses of various samples of iron and steel sent by the Austrian Alpine Mining Company of Eibiswald to the General Assay Office at Vienna in 1894 and 1895:—

	a.	b.	c.	d.	e.	f.	g.
	Per Cent.						
Carbon (combined) .	0·195	0·913	0·491	1·520	2·330	0·52	0·73
Silicon .	0·003	0·224	0·410	0·630	1·840	0·39	0·57
Phosphorus .	0·099	0·033	0·038	0·006	0·005	0·03	0·07
Sulphur .	0·037	0·006	0·009	0·020	0·030	0·02	0·10
Manganese .	0·343	0·219	0·280	1·140	0·180	0·36	0·81
Copper .	0·135	0·012	...	0·002	...	0·02	0·08
Tungsten .	...	2·133	3·251	28·270	66·200	...	...
Nickel .	...	0·008	...	...	...	4·63	trace
Chromium .	...	...	...	...	...	...	0·75
Tin .	...	...	...	0·720	...	...	...
Titanium .	...	...	...	...	trace	...	...
Iron .	99·188	96·452	95·521	67·620	29·200	94·03	96·89

(a) Tin plate after removing tin; (b) and (c) tungsten steel; (d) and (e) ferrotungsten; (f) nickel steel; and (g) chrome steel.

\* *Glückauf*, vol. xxxiii. p. 89.

† *Berg- und Hüttenmännische Zeitung*, vol. lv. p. 402.

## II.—THE OPEN-HEARTH PROCESS.

**Improvements in Steel Manufacture.**—Last year was not an especially favourable one to the adoption of improvements or to experiments in the way of improvements, and but few changes can be reported. In steel manufacture the tendency to the development of the open-hearth process continues. The number of open-hearth furnaces in operation has increased during the year, and more new furnaces will shortly be ready to start. A considerable proportion of these are basic furnaces, and the basic open-hearth process has been so far developed as to create a steady demand for basic pig iron, which is now regularly quoted in the markets. It has also operated to increase the demand for heavy steel scrap, which is used in this process. The Troy Steel and Iron Company during the year started its basic Bessemer converters, which have been running successfully on pig iron made from Lake Champlain ores, and have been turning out steel of excellent quality. This is the first use of the basic Bessemer process in the United States, where the open-hearth process has found much more favour in dealing with iron high in phosphorus.\* With the revival of business a still further development may be expected. Little or no advance has been made in steel-making at the South, although it is stated that the manufacture of basic steel on a large scale from Alabama pig iron will shortly be undertaken.

**The Manufacture of Open-Hearth Steel.**—According to E. G. Odelstjerna,† it is advisable to re-carburise open-hearth metal with carbon. The coal used must be perfectly dry. If at all damp, explosions ensue. The method of re-carburising by tapping the metal on to dry bricks made of lime and the carbon material used would be perhaps advantageous, but the patent charges are too high. It is unpractical, too, to add the various additions made to basic metal into the furnace. Only nickel can be added in this way, either in the metallic form or as its oxide, as it is without action on the furnace walls and remains in the iron bath until all the iron is oxidised. It thus passes completely into the steel produced. But other additions, such as chromium, silicon, or manganese, ought to be first melted in crucibles and then added

\* *Engineering and Mining Journal*, vol. lxiii. p. 14.

† *Wermåndiska Annaler: Berg- und Hüttenmånnische Zeitung*, vol. lv. p. 417.

direct into the ladle when tapping, as it is only possible in this way to be sure that the exact percentage intended has passed into the steel made. Silicon and manganese readily attack basic linings.

B. Dawson \* briefly reviews the last year's progress in open-hearth steel-making, and refers to mechanical charging devices, new valves and furnaces, the trial of the direct process at Landore, the removal of sand from pig iron, and other details. The Stockman process for treating phosphoric iron with a mixture of iron sand and nitrate of sodium is mentioned, and the Bertrand-Thiel process is discussed at some length.

**Modern Forms of the Open-Hearth**.—Illustrations are published by H. Wedding † of the tipping open-hearts in use in the United States. The improvements connected with the rendering of the regenerator chambers free of access, and danger from accidents to the furnace-charge, are also dealt with.

**The Basic Open-Hearth Process.**—E. H. Saniter ‡ discusses the prospects of the open-hearth process, which, in his opinion, will be more extensively adopted, and gives the following figures relating to charges made with this process using desulphurising agents:—

Pig iron used—	Per Cent.	Per Cent.	Per Cent.
Silicon . . . . .	0·75	1·5	0·2
Sulphur . . . . .	0·2	0·35	0·4
Phosphorus . . . . .	3·0	1·5	1·6
Manganese . . . . .	1·0	0·5	nil.
Steel made—			
Carbon . . . . .	0·15	0·20	0·15
Sulphur . . . . .	0·045	0·055	0·045
Phosphorus . . . . .	0·045	0·02	0·04
Manganese . . . . .	0·50	0·50	0·60
Cwt. of material used per ton of ingots—			
Pig iron . . . . .	16·08	16·23	12·0
Steel scrap . . . . .	5·33	5·16	8·75
Ferromanganese, 80 per cent. . .	0·1	0·12	0·12
Ore . . . . .	4·42	2·14	0·66
Limestone and lime as lime . .	3·69	3·24	2·26
Calcium chloride . . . . .	0·14	0·35	0·25
Fluor spar . . . . .	0·12	0·20	0·14
Yield of ingots per cent. of metals .	93·18	93·0	95·2

\* *Iron and Coal Trades Review*, vol. liv. pp. 165-166.

† *Glaser's Annalen*, vol. xxxviii. pp. 166-173; *Berg- und Hüttenmännische Zeitung*, vol. lvi. p. 21.

‡ *Iron and Coal Trades Review*, vol. liv. p. 175.

It depends on local circumstances whether it is better to desulphurise the pig iron in the ladle first or afterwards in the steel furnace.

**The Bertrand-Thiel Process.**—P. C. Gilchrist\* deals fully with the Bertrand-Thiel process of open-hearth steel-making. Two furnaces or series of furnaces are employed instead of one furnace, and the temperature is sufficiently high to cause the metal flowing from the first furnace to give off copious reddish-brown fumes. The quality of metal obtained is equal to Swedish made from non-sulphurous pig. A yield hitherto unapproached is obtained, and the author thinks that 100 of pig iron will produce more than 100 of steel, when the use of scrap is either given up or when it is melted differently. The speed of working is increased. Possibly this speed will be twenty-four charges in twenty-four hours from five 20-ton furnaces, or 480 tons for twenty-four hours with four primary and one finishing furnace, the latter only receiving liquid metal from the four primary furnaces, and not being used to melt either pig iron or scrap. In four charges the percentage of scrap used and of loss was as follows :—

Scrap used, per cent. . . . .	57·5	57·5	20·47	10·0
Loss, per cent. . . . .	8·29	7·28	8·4	7·83

In another charge, using 30 per cent. of scrap, the total metal charged equalled 20·06 tons, and the yield of steel was 20·13 tons. In melting the scrap some must be oxidised, but is reduced again by the metalloids, and the loss is hidden. When no scrap is used and more ore is charged, the yield may be brought over 100 per cent. The intense heat permits the oxidation of silicon, phosphorus, carbon, and manganese to take place with more ease and rapidity than formerly ; it also liquefies the wrought iron derived from the ore as formed, so that all the ore used can be and is charged with the pig. The transfer from one furnace to another gets rid of the voluminous slag and enables the steel to be got ready for casting. If in the oxidation above referred to the oxygen comes from the air, the yield of iron must be less than 100 per cent., owing to the elimination of metalloids ; but if it comes from the ore, provided there be heat enough, iron is liberated and passes into the steel, so that more impure iron will give a greater yield. The paper itself gives full details of four charges, and these may be summarised as follows :—

\* Reprint of a paper read before the Cleveland Institution of Engineers, December 14, 1896, with additional matter. A copy has been presented by the author to the Library of the Institute.

In the primary furnace the weights of materials charged were as follows, the quantities being in tons:—

Charge.	Pig Iron.	Scrap.	Ore.	Lime.
I.	8·5	3·5	1·1	1·55
II.	8·5	3·5	1·1	0·55
III.	11·0	...	1·75	0·5
IV.	11·0	...	1·75	0·5

In the secondary furnace the materials employed, in addition to the molten metal tapped from the primary furnace, were as follows, the weights being in tons:—

Charge.	Pig Iron.	Scrap.	Ore.	Limestone.	Lime.
I.	...	8·0	0·2	0·8	0·4
II.	...	8·0	0·2	0·8	0·4
III.	2·6	3·5	1·2	0·6	0·2
IV.	4·3	1·7	1·5	0·6	0·15

In the first and second charges the lime and ore were added when the metal was tapped from No. I.; in the third and fourth charges, 0·2 ton of the ore and the lime were similarly used.

The analyses of the metal at various stages, both according to the Kladno and the English analyses, are given in full. Those extracted below are from the author's tabular summary:—

	C.	Si.	P.	Mn.
<b>First—</b>				
Primary charge . . . . .	2·65	1·15	1·77	0·36
Do. tapped metal . . . . .	1·06	0·056	0·991	0·068
Secondary charge . . . . .	0·63	trace	0·626	0·170
Do. after 15 minutes . . . . .	0·253	trace	0·043	0·037
<b>Second—</b>				
Primary charge . . . . .	2·65	1·15	1·77	0·36
Do. tapped metal . . . . .	0·923	0·065	0·961	0·036
Secondary charge . . . . .	0·954	0·043	0·608	0·121
Do. after 15 minutes . . . . .	0·059	trace	0·025	0·027
<b>Third—</b>				
Primary charge . . . . .	3·74	0·98	0·62	3·07
Do. tapped metal . . . . .	3·32	0·079	0·048	0·097
Secondary charge—	2·02	0·14	0·077	0·783
Do. after 15 minutes . . . . .	0·07	0·018	0·005	0·067
<b>Fourth—</b>				
Primary charge . . . . .	3·74	0·98	0·62	3·07
Do. tapped metal . . . . .	2·12	0·032	0·035	0·082
Secondary charge . . . . .	2·29	0·172	0·069	0·685
Do. after 15 minutes . . . . .	0·017	trace	0·034	0·051

The reprint of the author's original paper, from which these details and figures are taken, contains full analyses and details of these four charges from different sources, and also drawings of the furnace at Kladno, and of arrangements proposed by Bertrand and Thiel. The discussion by Messrs. Cooper, Panton, Darby, Ainsworth, Bell, Steel, Colville, Eccles, Bagley, Milton, Head, and Davis is appended, and also notes by J. E. Stead on the effect of silicon and phosphorus in fluid iron when mixed with or brought into contact with fluid oxide of iron, and by F. W. Harbord and T. Twynam on the heat absorbed or evolved by the action of ferrous oxide.

B. Dawson \* criticises the Bertrand-Thiel process, and points out its advantages and disadvantages.

**Thwaite's Steel Furnace.**—Illustrations have been published † of the steel furnace designed by B. H. Thwaite, in which the chambers for pre-heating the gas are omitted, and only two chambers are used for heating the air. These are placed above the furnace, and are worked alternately by moving a butterfly valve between them. Air is introduced under slight pressure. A diagram is given to show the progress of conversion during a heat made in this furnace. Some criticism of this type has also appeared,‡ in which it is pointed out that leakage at the air valve is unimportant.

**The Scholtz Open-Hearth.**—Illustrations are given of this form of open-hearth. § The furnace rests on columns, and the gas and air inlet leads are entirely separate. They are mantled, have slag pockets, and not only the inlets but the raiing leads are of numerous separate portions, preventing too early an admixture of air and gas, and admitting of ready repairs. Cowper regenerators are used, and these are divided by a wall into two parts for gas and air. Water valves are used. The roof of the furnace can be made in three sections. Numerous advantages are claimed for this furnace over the ordinary type.

**The Alexandroffsky Steelworks, Russia.**—This steelworks is in the Moscow district. || In addition to wood and charcoal, South

\* *Iron and Coal Trades Review*, vol. liv. p. 166.

† *Engineer*, vol. lxxiii. pp. 160-161.

‡ *Ibid.*, pp. 194 and 212.

§ *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xiv. pp. 89-90, with six illustrations.

|| *Stahl und Eisen*, vol. xvi. pp. 861-864.

Russian and foreign coke, coal from the Donetz basin and over 20,000 tons of naphtha are used as fuel. This latter can compete with coke and charcoal for metallurgical purposes, but is more expensive than wood when used under the boilers. The works possesses two blast-furnaces and six open-hearths, together with a rolling-mill. The charge of the open-hearths consists of 80 per cent. of pig iron and 20 of ore, the yield being at about the rate of 105 or 110 per cent. of the pig iron charged. When there is an adequate quantity of scrap available the charge is 50 per cent. of the latter and 50 of scrap.

The pig iron is charged in a fluid state into the open-hearths, the other portions of the charge are pre-heated in a welding furnace before being charged into the open-hearths. Each furnace is provided with four gas-producers, but using forced blast two suffice for each furnace. The coal used contains 30 per cent. of volatile matter. One of the open-hearths has an out-turn of 41 tons in twenty-four hours, and the other is larger, taking a 20 or 22 ton charge. Dimensions of the smaller furnace are given. The hearth consists at the bottom of chrome iron ore or of magnesite, the upper portion being of dolomite. The sides and roof are of Dinas brick. The consumption of fuel is about 45 per cent. of the iron made.

The charcoal in the Moscow district is made without any attempt at the collection of the by-products, tar excepted, and the yield in the Meiler method used is about 55 per cent. of charcoal. Peat is employed at many of the works. It contains from 25 to 30 per cent. of hygroscopic moisture, and from 4 to 10 per cent. of ash.

**The Putiloff Steelworks, Russia.**—This steelworks gives employment to 6000 workpeople. It possesses twelve open-hearths; seven of these furnaces, using basic lining, make a soft ingot metal, while the other five make a harder metal and are acid lined. This latter material is also used for steel castings. The annual out-turn includes 60,000 tons of steel and 1500 tons of special castings. In addition there is from the Bessemer plant a monthly out-turn of about 5000 tons, together with castings, puddled iron, and rolling-mill products. Among the products of these works are armour-piercing projectiles and armour-plates. Tool-steel is also an important product of this works. Carbon, tungsten, and chromium steels are made. The carbon steel is of different percentages according to its number. Thus, No. 5 contains 0·5 of carbon, and No. 12, 1·2 per cent. The hardest kinds made are Nos. 11 and 12. It is used for all kinds of

drilling, &c., tools, where great hardness is required without concussion or shock, and is hardened by heating to a dull red or a dull cherry red and then plunging into water or oil of 18° or 20° C. Nos. 7 and 8 are medium hard, and more resisting to concussion, and are used for chisels, drills, swords, screws, &c. Great care is necessary in the treatment of these. Nos. 6 and 5 are tougher, and are more readily weldable. Heating and hardening are effected at a bright red heat, and with the hardening fluid at a temperature of from 15° to 18° C. These numbers are specially adapted for hammers, knives, surgical instruments, &c.

Chrome steel is made of three brands, A, B, C. A serves for tools which are not subject to shock, and great care is necessary in hardening it. Several operations are necessary, and amongst these are twice heating and hardening. Chrome steel B is tougher, and can be made very hard. Chrome steel C is remarkably soft when annealed and is very tough. Indeed, the chrome steel is especially marked by the readiness it can be made by suitable treatment in hardening more or less hard or tough as may be required.

The tungsten steel made, besides containing much tungsten, also contains a good deal of carbon and manganese. Brand A does not need hardening, and will not, indeed, stand this. Tools made of this steel possess the curious property, that in their unhardened condition they do not suffer if cooled suddenly when made hot by the work done in the course of their use. The steel is therefore very useful for turning tools and all tools generally in which a circular movement is employed, and especially in cases where a rapid working is necessary and where thick shavings have to be taken off. Brands B and C of this tungsten steel are useful both for hard tools and for large and small magnets.\*

### III.—THE BESSEMER PROCESS.

**History of the Bessemer Process.**—Sir Henry Bessemer† has given an account of the early origin of the Bessemer process of steel manufacture as developed at his bronze-powder manufactory in London. From the first attempts in a reverberatory furnace, which led

\* *Stahl und Eisen*, vol. xvi. p. 962.

† *Transactions of the American Society of Mechanical Engineers*, vol. xviii. (advance proof).

him to try the action of air applied more directly, the process is traced through the various experiments in which crucibles, fixed converters, and movable converters were used, and of these illustrations are given to show the steps by which converters and their accessories, as now used, were evolved.

**Steelworks in Upper Silesia.**—According to F. G. Bremme,\* there is only one acid Bessemer plant in Upper Silesia, at the Königshütte. The basic Bessemer process was introduced in 1884. At the Friedenshütte three basic converters are supplied with metal direct from the blast-furnaces, and the plant comprises a pig iron mixer of a form not elsewhere in use as yet. The Upper Silesia iron ores being too poor in phosphorus to yield a pig iron sufficiently rich in that element for use in the basic Bessemer process, and the imported irons being also too poor in phosphorus, it is found necessary to use over again in the blast-furnace some of the phosphoric slag produced in the Bessemer process itself. Seventeen basic and one acid open-hearth are now in use in the district. The author gives statistical details relating to the iron trade production of Upper Silesia, and deals also with the various iron trade industries and questions of transport.

**The Reschitza Steelworks.**—These steelworks, which have been frequently dealt with in previous abstracts, are again described.† Up to 1893 the plant consisted of one coke blast-furnace and three charcoal furnaces, the former making 60 tons a day, and the three latter together 50 tons a day of Bessemer pig iron. Now the plant has been remodelled, and the out-turn is about 20 per cent. greater than before. In 1895 some 42,000 tons of Bessemer pig iron was produced. The ores smelted are mentioned and the plant now in use described. It consists of one coke blast-furnace 66 feet high and two 17-metre charcoal blast-furnaces. Eight Whitwell stoves are in use, yielding blast of a temperature of 600° C. The blast-engine used is of 800 horse-power. For the remelting of the pig iron for use in the Bessemer converters, a cupola capable of melting five tons of iron per hour is employed, while two other cupolas and six reverberatories are in use in the foundry.

A Bessemer plant was first put into operation at this works in 1868. Now there are four 8-ton converters in operation. In 1895 they pro-

\* *Stahl und Eisen*, vol. xvi. pp. 762-763.

† *Berg- und Hüttenmännische Zeitung*, vol. lv. p. 413.

duced 24,000 tons of ingots, all of which was made into rails. At the present time \* both the Bessemer plant and the open-hearth plant are undergoing reconstruction, two 15-ton open-hearths alone remaining untouched. In place of the four 8-ton converters and four 8-ton open-hearths hitherto in use, one joint plant, contained in a single building, is in course of erection. This will consist of three converters and three 20-ton open-hearths. The converters and furnaces are placed in a single row, one casting-pit 65 yards long being common to them all. There are three groups, each consisting of four producers, placed in a separate building at the back of the open-hearths. These are served by blast delivered from three electrically-driven Enke blowers. The annual out-turn of open-hearth steel is estimated in future at 45,000 tons, or even over 50,000 tons if required.

The crucible steel plant at this works was erected in 1889, and is capable of producing 1000 tons of crucible steel a year. The open-hearth steel-casting plant at this works is also described.

There were formerly three double and six single puddling-furnaces at the Reschitzka ironworks, but of these only two single furnaces now remain in use. The others have been replaced by two gas-puddling furnaces with revolving hearths on the Pietzka system. The rolling-mills are also described.†

**Steelworks in Russia.**—Accounts have been given in some of the technical journals ‡ of the metallurgical and other exhibits at the Nijni-Novgorod Exhibition held last year. A cast cylinder and large spur-wheel and a number of special steels were shown as examples of manufactures from the works at Perm, where guns up to 11½ inch calibre are made. The Slavianoff process of electric welding was exhibited. Art castings of high quality were abundant. Structural iron plates and sheets were largely represented, and much of these come from the Ural districts, where there are twenty open-hearth furnaces and six Bessemer converters. Very generally these furnaces are made with chrome iron ore bottoms. Rails made by several works were also shown.

**Steelworks in the United States.**—F. Hilton § gives a number of illustrated descriptions of the steelworks in the United States. At the Edgar-Thomson Works at Braddock, Pennsylvania, there are

\* *Berg- und Hüttenmännische Zeitung*, vol. iv. p. 387.

† *Ibid.*, vol. lvi. p. 69.

‡ *American Manufacturer*, vol. lix. p. 836.

§ *Iron and Coal Trades Review*, vol. liv. pp. 172, 262, 295, 473.

seven blast-furnaces, each making 400 tons daily. All the metal is taken to two 150-ton mixers, which supply the steelworks. There are four 20-ton converters, each taking a charge of 18 tons. Ingots are cast 16 inches square, heated in soaking pits, rolled to 8 inches square, and cut up for reheating and rolling into rails.

At the Johnson Company's Steelworks at Lorain on Lake Erie there are four cupolas 25 feet high and 10 feet in diameter, in which iron is melted for conversion. The Bessemer shop, 85 by 90 feet, contains two 12-ton converters, two spiegel cupolas and a ferromanganese heating furnace. Ingots are cast on bogies, two ingots at a time. Holley's dry bottoms with loose nozzle lasting twenty-four blows are used. Ingots pass through two six-hole soaking pits to a 38-inch cogging-mill coupled direct to a double cylinder reversing engine with 55-inch cylinders and 60-inch stroke. The rail and structural mill covers 820 by 440 feet, and contains two roughing trains and a finishing mill driven by reversing engines, one 48 by 50 and the other 45 by 48 inches. Electric coal conveyors and cranes are extensively used.

At the Duquesne Works, of which the blast-furnaces are fully described elsewhere in this volume, there are two 10-ton converters which have made 38,000 tons of ingots in the month. The rolling-mills are also described.

The Joliet Works also contain two converters, and illustrations are given of the Wellman charging-machine.

**Basic Slag.**—F. E. Thompson \* states that practically only Bessemer basic slag is used for manurial purposes, as open-hearth basic slag is made with iron containing less phosphorus, so that it is not sufficiently rich. The slag is sometimes allowed to weather before grinding, but often it is ground at once to obviate drying. It is readily broken up by pick and shovel, and is ground in a ball-mill. This type of mill is preferable, as it is not choked by metal shot. At Pottstown the standard of fineness adopted was that 75 per cent. should pass a 150-mesh sieve and 90 per cent. a 100-mesh sieve. Less than 1 per cent. was retained by a 20-mesh sieve. A few German works have adopted the practice of charging part of the lime and tapping off the rich slag before completing the blow with a second addition of lime. The author then discusses the analysis of basic slag, and recommends that the Wagner method should be adopted as the standard in America. Commercial considerations are also dealt with.

\* *Iron Age*, vol. lix. No. 1, pp. 9-11.

H. Dubbers \* has made an exhaustive inquiry into Wagner's process, and comes to the conclusion that the time of shaking with the ammonium citrate solution (half an hour) is quite insufficient, and that a larger quantity of acid ammonium citrate solution should be used. The author recommends using 500 cubic centimetres of liquid, containing 10 grammes of free citric acid and 5 grammes of the same neutralised by ammonia. The shaking should be continued for about four hours.

\* *Zeitschrift für Angewandte Chemie*, 1896, pp. 468-473.

## FURTHER TREATMENT OF IRON AND STEEL.

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**Fluid Compression of Steel**.—H. K. Landis\* opposes the view taken by W. F. Durfee, that blow-holes are the causes of most defects in steel. Armour-plates are not made of fluid compressed steel, but blowholes and cracks are obviated by the use of heavy sink heads, which are kept fluid by a refractory lining. The fluid compressed steel is usually reserved for less massive forgings, and the process of making these is described. The mould is composed of cylindrical sections bolted together, and resting on a sliding platform. It is filled from above, and run under a fixed plunger, after which it is raised by hydraulic power. The mould is lined with staves of cast iron about two inches square, slightly bevelled on their edges, and grooved to allow gas to escape. Inside the staves is spread fireclay mixed with ground firebrick in a damp state. The plunger is also coated with fireclay. Before pouring, the mould is heated. When the pressure is applied, the mould rises over the plunger, and gas escapes continuously.

**Face Hardening**.—In the Demenge process for face-hardening, one side of the mould is lined with carbonaceous material, and the opposite side is formed as a chill, consisting of a mass of iron through which water may be circulated. The ingot takes up the carbon on the one side to an extent controlled by the cooling effect on the other. In one test an ingot of 6600 lbs. was cast 16 inches thick, and reduced by rolling and forging to a plate 4 inches in thickness. It showed a gradual reduction in the carbon from 1·75 per cent. on one side to 0·15 on the other.†

\* *American Manufacturer*, vol. lix. pp. 727-728.

† *Iron Age*, vol. lix. No. 6, p. 15.

**Hardening Steel in Carbolic Acid.**—According to Levat,\* steel tempered in a solution of phenol possesses greater hardness, elasticity, and flexibility than when tempered in water. Two cold chisels of high quality Holtzer cast steel were heated to cherry redness, and dipped, one in water and the other in a solution of the carbolic acid of commerce, until the blue tint came on. With these chisels, iron puddle-bar and extra-hard white forge pig were chipped, when it was found that the edge of the water-hardened tool was notched, while that of the one hardened in carbolic acid solution stood well. A bar of fagotted steel, and another of ordinary cast steel, raised to a white heat and hardened to a blue tint in a carbolic acid solution, showed a finer fracture than bars not so treated. The carbon content was not increased, but bending tests showed a slightly greater elasticity.

**The Double Hardening of Steel.**—The double hardening of steel consists in reheating the once-hardened steel to a somewhat lower temperature a second time, and then again hardening. According to A. Godeaux,† the first investigations of the double hardening of the mechanical behaviour of ingot metal were made by Walrand and Cottin at Le Creusot, who were led to make the experiments by the peculiar appearance of a fracture which they attempted to imitate. Auscher subsequently published the results of some experiments on this same subject, which corroborated the results obtained by the previous experimenters, who showed that by this second hardening the hardness, elasticity, and tensile strength were all increased, while the brittleness under shock diminished. At the Bascoup Collieries this double-hardened metal has been used successfully for various purposes, and at the Indret Steelworks the double-hardening process is employed for all cast or hammered steel manufactures. *Stahl und Eisen* ‡ points out that though the test results published by Godeaux do not in themselves prove any marked improvement in the character of the metal over that produced by the ordinary hardening process, yet that it appears that the process is one which is worthy of a thorough investigation, and that this should ascertain too how far the success of the process is dependent on such secondary points as the temperature of the water, &c.

\* *Comptes Rendus de l'Académie des Sciences*, vol. cxxiii. p. 945.

† *Revue Universelle des Mines*, vol. xxxvi. pp. 224-236.

‡ Vol. xvii. pp. 49-50.

**Annealing.**—H. K. Landis \* urges the advantages of annealing for all steel forgings and castings in order to relieve strains. For this purpose they should be heated up to between 900° and 1600° F., and allowed to cool more or less slowly, according to circumstances. If a piece is to be machined, it should be heated to 1300° F., and allowed to cool slowly in the furnace. Simply to remove strains, heating to 1000° F. and air cooling is sufficient, but a greater toughening effect, depending on the carbon present, is obtained by cooling more rapidly. Scale is best prevented by enclosing the article in an air-tight casing filled with fuel gas or oil vapour. Pickling is condemned. The annealing of work passed through a series of drawing operations is then referred to, and the experiments made by Charpy are mentioned as forming a basis for annealing test specimens before subjecting large work to the operation.

**Hollow Steel Forgings.**—H. F. J. Porter † further describes hollow steel forgings, and gives several instances of shafts made in this way for steamers and other purposes. The strength of steel and of nickel steel hollow shafts is compared with that of solid shafting.

**Heating Furnaces.**—Two continuous billet-heating furnaces erected in Philadelphia are stated to have given much satisfaction. The billets are loaded on to a truck, from which they are pushed off into the furnace one at a time by a hydraulic pusher. This action also causes a heated billet to fall out of the other end of the furnace into an inclined pipe, which leads it to a gore plate, from which it passes to the rolls. Thus the billet is not handled between the time it is loaded until it has gone through the first pass of the rolls.‡

**Cast Steel Ropes at Przibram.**—K. Habermann § states that at the chief shafts in the Przibram district for some years past winding-ropes of "patent" or "extra-crucible cast steel wire" have been used. These wires are stated to have a tensile strength of 396·8 lbs. per 0·35 inch. The round ropes consist of eight strands, each containing six wires, or together forty-eight wires. The strands of these ropes have

\* *Iron Age*, vol. lviii. pp. 854-855.

† Paper read before the Western Society of Engineers, through the *American Manufacturer*, vol. ix. p. 20. Compare *Journal of the Iron and Steel Institute*, 1896, No. II. p. 369.

‡ *Iron Age*, vol. lviii. p. 717.

§ *Berg- und Hüttenmännische Zeitung*, vol. iv. p. 193.

well-greased hemp cores. The main core of the rope, too, is well greased, with a view to prevent the rusting of the inner portions of the rope. The shafts being more than 3300 feet in depth, the thickness of the rope undergoes a gradual diminution along its length. This is effected not by diminishing the number of the wires, but by lessening their diameter. The upper 984 feet consists of No. 25 wire; then Nos. 24, 23, and 22 wire are used, each for a length of 658 feet; and subsequently a piece, 1120 feet in length, of No. 21 wire, of the German gauge. The rope is 1·16 inch in diameter at the top, and 0·93 inch at the bottom. It weighs 2·439 tons. The wires are soldered together, and as the joints have only two-thirds of the tensile strength of the wire itself, such joints are spread over a considerable length along the wire, thus preventing the tensile strength of the rope sustaining any great diminution through them. Of two ropes at the Kaiser Franz-Josef Shaft, the one was 35·1 and the other 38·1 months in use. In 92,957 turns, these raised from an average depth of 596·4 metres 143,475 tons. These ropes possessed a much longer working life than other crucible steel ropes in use in the same district.

**The Largest Boiler-Plate.**—*Stahl und Eisen*\* gives the following comparison between the largest boiler-plate yet made, which is stated to be that of which the dimensions are given below, exhibited by Messrs. Krupp at Chicago, with others produced by the Dowlais Works and by the Stockton Malleable Iron Company:—

	Krupp Plate.	Dowlais Plate.	Stockton Plate.
Length, metres . . . .	20·0	21·00	23·240
Breadth, metres . . . .	3·3	1·28	1·524
Thickness, millimetres . . . .	32·0	15·00	15·000
Surface, square metres . . . .	66·0	26·98	35·400
Weight, kilogrammes . . . .	16,200·0	4114·00	5588·000

**Steel Railway Waggons.**—The next revolution in the use of steel will be the building of complete steel railway waggons. It is now possible to build a complete steel waggon for about the same cost per ton carrying capacity as a wooden waggon. There is a saving in dead weight and in repairs, and there is an absence of risk from fire. One American railway company has decided to have built 200 steel waggons, specifications and drawings of which have been published

\* Vol. xvi. p. 745.

in the *Railroad Gazette* (vol. xxix. p. 143). The waggons are of 50-ton capacity of mild steel. They are 30 feet long, 8 feet 11 inches wide, and 8 feet 9 inches high from the top of rail to top of body.

**Cast Steel in Locomotive Construction.**—In an extract from a paper read before the New England Railway Club, J. E. Sague \* gave reasons which have led to the wide substitution of steel for cast and wrought iron.

An extract has appeared from a paper read by Barba † before the New England Railway Club showing the adaptation of steel to this work.

**Steel Rails.**—A diagram published in the *Engineering News* (vol. xxxvi. p. 157), showing by superimposed sections the rapid increase in size and weight of the rails used on the Denver and Rio Grande Railway during the last twenty-five years, is a striking indication of the marvellous growth of the railway industry during the last quarter century. There are eight sections, ranging from 30 lbs. to 85 lbs. per yard, dating from 1871 to 1896, and representing three different types of head.

In response to a circular of inquiry, several of the American manufacturers have furnished more or less exact details as to the size of rails now being rolled. In all cases a steady advance is shown. The South Lackawanna Iron and Steel Company give the most complete table, although only for two years, and this is given in an abridged form below :—

Lbs. per Yard.	Rolled in 1891.		Rolled in 1896.	
	Per Cent.	Per Cent.	Per Cent.	Per Cent.
100 to 85	none	20·83		
80 „ 72	50·76	52·69		
70 „ 60½	32·00	24·79		
60 „ 56	17·24	1·69		

The Illinois Steel Company give the average weight as 63·75 lbs. in 1889, 67 lbs. in 1892, and 71·08 lbs. in 1895. The standard sections proposed by the American Society of Civil Engineers do not appear to have been widely adopted, several works rolling none of them; but the Illinois Steelworks rolls 38 per cent. of this section. Other improved

\* *Railway Review*, December 26.

† *American Manufacturer*, vol. lix. p. 911.

sections, such as Dudley's and Hunt's, are also rolled, but most of the buying recently has been in small lots for renewals.\*

**Structural Steel.**—Detailed drawings have been published † of the structural framework of the Astor Hotel in New York. The site occupied by the building is 98 feet 9 inches by 335 feet. All the main structural work is of mild steel, of which the building will contain about 10,000 tons.

How important the construction of fireproof buildings has become as a factor in the consumption of iron and steel is well shown by the thirty-storey office building in New York, detailed drawings of which are published in the *Engineering News*.‡ The total metal in this structure will reach 9000 tons. This is as much steel as would be required to lay 100 miles of railway with 50-lb. rails.

**American Steel Bridges.**—M. Foerster § publishes a number of illustrations relating to recent steel bridges in the United States. Descriptions accompany the illustrations, which comprise the bridge over the Mississippi between Davenport and Rock Island, the turning bridge over the Harlem at New York, and others. In this last-named bridge the material used was required to contain less than 0·08 per cent. of phosphorus and 0·04 per cent. of sulphur. Other chemical and mechanical data are not given.

A. Ostenfeld || has published an elaborate description of the construction of iron and steel bridges in the United States.

**The Oldest Iron Bridges.**—Mehrtens ¶ observes that the idea of building iron bridges is stated by Gauthey to have been mentioned in Italian writings of the sixteenth century. The first fixed iron bridge—not suspension—was built over the Severn in 1779, and of this and of a German bridge of the date 1794 illustrations are given by the author, who also discusses them. Both are still in excellent preservation and daily use. They are constructed of cast iron.

\* *Railroad Gazette*, through the *Iron Trade Review*, vol. xxix. No. 52, p. 10.

† *Engineering News*, vol. xxxvi. pp. 412-415.

‡ Vol. xxxvi. p. 232.

§ *Stahl und Eisen*, vol. xvii. pp. 271-276, with eight illustrations.

|| *Den Tekniske Forenings Tidsskrift*, vol. xx. pp. 261-288, with three plates.

¶ *Stahl und Eisen*, vol. xvi. pp. 1002-1004, with four illustrations.

**Manufacture of Tubes.**—E. C. R. Marks,\* in a series of articles, describes the manufacture of iron and steel tubes, giving extracts and illustrations from various patents relating to this subject.

An illustrated description has been published † of the tube-mill of the United States Projectile Company at Brooklyn. Swedish steel in round bars, 6 to 8 feet long and 3 to 4 inches in diameter, is cut up into lengths weighing about 20 lbs. each, which are heated to a bright red heat, and formed into cups in a series of hydraulic presses. After annealing and pickling, these cups are drawn cold in draw-benches, with repeated annealing and pickling. Hydraulic power is exclusively used, a water pressure of 2500 lbs. to the square inch being employed.

A fairly detailed account of the method of making bicycle tubing by the Pope Tube Company of Hartford, Connecticut, has been published,‡ together with a plan of the works and numerous illustrations of the plant. The material used is nickel steel in plates and 0·50 carbon steel § (fifty carbon steel) in hollow billets 4 feet long. The main building, 237½ by 165 feet, contains the hydraulic draw-benches presses, and annealing furnaces, and an annexe, 160 by 89 feet, contains the finishing department and offices, &c. From the nickel plates as received a circular blank is stamped out and reduced by cupping and drawing in hydraulic presses, and then passed to hydraulic drawing presses, in which the tube is drawn over a mandrel and through a die. These draw-benches range from 8 inches diameter of cylinder and 8 feet stroke to 6 inches diameter and 22 feet stroke. Water pressure is 1200 lbs. After each pass through the draw-bench, the tubes are annealed, being packed into iron tubes with screwed end-caps. The retorts are heated in gas-fired furnaces, and then transferred to cooling-ovens, and finally to cooling-floors before they are emptied. All the drawing is done cold, and no pickling is required. The tubes are straightened by rolls or by hand and cut to length. Oil and dirt is removed by washing with a solution of hot whale-oil soap. The testing machinery consists of a 100,000-lb. Emery machine and various appliances for testing the endurance of frames and wheels. The boilers and hydraulic plant are also illustrated.

The story of the establishment in the United States of the cold-drawn seamless steel tube industry is told in a recent issue of the

\* *Practical Engineer*, vol. xv. pp. 52, 123, &c.

† *Iron Age*, vol. lix. No. 11. pp. 1-3, with illustrations and plate.

‡ *Ibid.*, No. 1, pp. 1-6; No. 2, pp. 1-5; No. 9, pp. 1-6.

§ *Journal of the Iron and Steel Institute*, 1896, No. II. pp. 389-410.

*Pittsburgh Dispatch.*\* Six years ago the art was shrouded in mystery, the process of drawing being kept secret. Two companies in England, the Weldless and the Credenda, were engaged in the manufacture. Owing to the immense amount of the tubing imported into the United States for bicycle manufacture, a company in Selby, Ohio, erected a tube-mill, and the first seamless cold-drawn steel tube was made in the States on July 24, 1891. This was the result of extensive research, two representatives of the company having been despatched on a secret mission to the English works. It required persistent ingenuity to gain access to one of these works; but, disguised as a workman, one of the envoys finally accomplished the task, and the works built are now the largest in the world, covering as they do six acres, and having a capacity of two million feet of tubing per month. The sizes turned out range from  $\frac{1}{2}$  to 3 inches in diameter, the metal used being imported Swedish steel. This account of the establishment of the cold-drawn seamless tube industry offers an explanation of the decline in the exports of English bicycle material to the United States.

**Welded Iron and Steel Pipes.**—J. G. Stewart † gives some notes on welded iron and steel pipes, of which the manufacture has progressed so greatly during recent years owing to the demand for water mains of lighter character than cast iron. The welded joint can be made satisfactory, and the use of a buttstrap riveted over the weld is condemned, as rivet holes weaken the pipe. A number of tests of pieces cut from welded pipes are given, and some old tests on the relative corrosion of iron and steel are quoted. The joints are also discussed.

S. F. Walker ‡ generally describes the process of electric welding, with special reference to the Thompson, Zerener, and Bernardos systems.

**Armour-Plate.**—C. J. Dougherty § has published a description of the procedure adopted in electrically annealing Harveyised armour on a battleship. The memoir is illustrated by photographs of annealing scupper-holes in the side armour on the U.S. battleship *Iowa* at the

\* Through the *Colliery Guardian*, vol. lxxii. p. 1063.

† *Transactions of the Institution of Engineers and Shipbuilders in Scotland*, vol. xxix. pp. 197-228.

‡ Paper read before the Bristol Channel Centre of the Institute of Marine Engineers, through the *Practical Engineer*, vol. xv. pp. 139-141.

§ *Cassier's Magazine*, vol. xi. pp. 406-411.

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Cramp Shipyard, the *Iowa* approaching completion, the annealing transformer and rheostat, and the alternating generator for the annealing. On the *Iowa* two complete annealing plants were at work day and night for three months. Six hundred holes were annealed in the side armour, 800 holes in each of the 12-inch barbettes, and about 500 holes in the diagonal armour, besides many others in the belt armour.

In an obituary notice of Sir John Brown,\* his description is referred to of his first method of rolling a 5-ton armour-plate,  $4\frac{1}{2}$  inches in thickness, from slabs 12 inches broad, 30 inches long, and 1 inch thick, built up to form bars and plates successively larger and thicker. He entered on this manufacture after seeing the early armour-plated French vessels.

An elaborate report † on the cost of armour-plate in the United States was presented to Congress in January last. A limited amount of information was afforded by the Carnegie and Bethlehem Companies, and in addition to this, the price of armour made in other countries, and any details gathered by the inspectors, are collected in this report, and enlarged upon with the view of showing that the United States Government is paying far too high a price for armour.

Other reports on the failure of certain ship-plates have also appeared, and have given rise to some discussion.‡

An extract has also appeared from a written statement submitted to the Senate Committee on Naval Affairs by H. C. Frick upon the question as to what should be the price of armour-plate. §

**The Manufacture of Bicycles.**—A description, accompanied by twenty-nine illustrations, is published by Hædicke || of the manufacture of bicycles. He considers that these had their origin in an invention of Hans Hautsch of Nüremberg in 1649, by which it was claimed that a person could cover a distance of 2000 paces in the minute. The author gives illustrations of some older forms of machine. He compares the different principles underlying the use of the tricycle and bicycle, and then enters into an elaborate detailed description of the methods of manufacture of the latter. He refers, too, to the improvements which have been gradually introduced into its manufacture, and

\* *The Engineer*, vol. lxxxiii. p. 5.

† *Iron Age*, vol. lix. No. 1, pp. 19-22; No. 3, pp. 20-21; No. 4, pp. 19-20.

‡ *Ibid.*, No. 1, pp. 6-7

§ *American Manufacturer*, vol. lx. p. 225.

|| *Stahl und Eisen*, vol. xvii. pp. 5-14 and 44-49.

to the rapid progress which this has made. In the United States alone, he considers, there are now perhaps 4,000,000 bicycles in use. The various parts of a bicycle are separately considered. The balls used in the ball-bearings are of glass-hard steel. Their shaping is effected in various ways, and either in the hot or the cold. The most primitive method in the cold was turning, and this has undergone development. Methods in the hot include stamping, rolling, and others. Hot methods are used chiefly for large balls. The various methods of preparation and treatment of these balls are described and illustrated. It is pointed out that every bicycle contains on the average over 100 of such balls. The wheels, driving parts, &c., are described, and the author next proceeds to a brief reference to the tyres used with such machines. The chains and the various other parts of the machine also receive attention.

**Manufacture of Locks at Velbert.**—E. Cremer \* deals historically with the manufacture of locks, and then passes to the manufacture of locks as now practised at Velbert, Germany, a town of some 20,000 inhabitants. It is carried on there as a kind of village industry.

**Cleaning Old Files.**—A. Gawalowski † observes that used files from the working up of iron materials should be first plunged into water containing copper sulphate. In this way any iron filings attached to the file are removed by their reducing action on the copper sulphate solution, while the teeth of the file itself are not much affected. The file should then be washed, brushed, and dipped into concentrated nitric acid till red fumes appear in quantity, washed with water and then rapidly dried in sawdust, coal-dust, or some similar material. When the files have been used for metals other than iron, the preliminary treatment with copper sulphate solution is unnecessary. Where the files are clogged with wood-dust, they should first be treated with concentrated, and, if possible, heated sulphuric acid. Spirits of wine, if thrown over the wet file and then set fire to, dries them in a satisfactory manner. Files cleaned in this way become sharp again, at least in part.

**Making Screws.**—Some illustrations ‡ have been published of the different types of machines used for making screws, such as wood

\* *Stahl und Eisen*, vol. xvii. pp. 97-100.

† *Ibid.*, vol. xvi. p. 695.

‡ *Iron Age*, vol. lviii. pp. 1008-1010.

screws by cold swaging or rolling a rod. The screws are formed by dies forced directly against the blank ; by flat plate reciprocating dies, and by circular dies working in opposite directions ; by two roller dies running in the same direction ; by three cylindrical rotating dies ; by dies formed on the sides of revolving rings ; and by three rollers acting successively.

**Stopping Cracks in Cast Iron.**—A. Demalght\* fills up cracks or porous spots in cast iron cylinders by filling such cylinders with ferric chloride solution, and exerting pressure until drops of the solution appear on the outside of the metal. Then the chloride solution is withdrawn, and ammonia forced into the metal in a similar way. Ferric hydrate is thus produced, and this, it is stated, effectively fills up any crack.

**The Oldest Iron Stove in the World.**—The oldest iron stove † in use is probably at Fessen, Saxony, in a room at the Gerlis Mill at that place. The stove is said to be several hundred years old. The front of the stove represents the birth of Christ, with the following words in raised letters above :—" Ehre sei Gott in der Hoehe und Friede auf Erden und den Menschen ein Wohlgefallen " (Glory to God, peace on earth, good will to men"). The side plates show the crucifixion, and the words " Christus ist gekommen, die Suender selig zu machen " ("Christ has come to save sinners"). The stove was bought some time ago at an auction at the Castle of Annaburg.

**Friction Horse-Power in Factories.**—A useful set of experiments on the power absorbed in the engine shafting and belting in works are recorded by C. H. Benjamin.‡ The engine was indicated both when the works were fully employed and when the engine was running light, and the results obtained are presented in various ways. At sixteen works from 40 to 77 per cent. of the power was used up in the shafting, and only the remainder was available for the machinery to be driven. There was, however, one notable exception, a well-arranged works where great attention was paid to oiling and keeping the shafting in order, and here the percentage was as low as 14.5 per cent. Large pulleys on countershafts, fast running belts, oiling and inspection are

\* *Engineering and Mining Journal*, vol. lxi. p. 110; *Oesterreichische Zeitschrift für Berg- und Hüttewesen*, vol. xliv. p. 634.

† *American Manufacturer*, vol. lx. No. 6, p. 207.

‡ Paper read before the American Society of Mechanical Engineers, through the *Iron Trade Review*, vol. xxix. No. 52, pp. 8-9.

recommended ; but it is pointed out that electric transmission would be advisable in many cases.

**Carborundum for Grinding Rolls and Wheels.**—F. A. Fitzgerald \* gives an interesting illustrated account of the manufacture of carborundum at Niagara Falls. There are five furnaces 16 feet long and 5 feet square inside, in each of which nearly 2000 lbs. of mixed sand, salt, sawdust, and coke are charged. Current equivalent to 1000 horse-power is used for heating each furnace, and 4000 lbs. of the carborundum are produced. This compound of silicon and carbon is now largely used in place of emery, and some particulars are given of the work done with grinding wheels made of this material and used for truing rolls and railway wheels.

**Economy in the Use of Steam.**—E. J. Duff † discusses the economical development and use of steam in iron and steel works. Higher pressures cannot advantageously be used in reversing-mills on account of the low cut-off. Neither is compounding successful, because full power is required directly the mill starts, and a starting valve such as used on locomotives for admitting full pressure to the low-pressure cylinder might probably lead to greater losses. Condensing systems appear to be equally impracticable for several reasons. The author, therefore, proposes a radical departure, and this consists in using high-pressure steam in the mill-engines, working them under a considerable back pressure, and using the exhaust steam in other engines for the gas-producers and for other purposes. In fact, it may be considered that the whole plant is to be worked by a compounded engine ; but the high-pressure cylinders alone are used for driving the rolling-mills, whilst the low-pressure cylinders are used for other purposes. In case of necessity, high-pressure steam would be passed through reducing valves to supply deficiency in low-pressure mains ; or, if there were an excess of low-pressure steam, it would have to be blown off. The author works out the economy to be effected, and summarises the advantages.

\* *Journal of the Franklin Institute*, vol. cxliii. pp. 81-95.

† *Journal of the West of Scotland Iron and Steel Institute*, vol. iv. pp. 134-143.

## PHYSICAL PROPERTIES.

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**Micro-Metallography.**—J. E. Stead \* generally describes the microscopic investigation of iron and steel, and shows that (1.) The approximate proportion of carbon present could be ascertained by comparison with standard specimens of known carbon content. (2.) It was frequently possible to determine whether or not a steel was a casting or forging. (3.) The microscope could show in many instances to what heat treatment the steel had been subjected. (4.) The change in structure produced by stresses on the cold steel could be most readily detected. (5.) Microscopic flaws and defects, and the presence of foreign matter, such as slag, &c., could be discovered. (6.) Segregation and unequal distribution of carbon could also be most easily seen on properly prepared and etched surfaces of steel.

**Micro-Mechanical Examination of Rails.**—J. E. Stead † refers to the investigations of J. T. Smith in 1875, who showed that weakness of used rails shown under impact tests was located entirely on the surface. Planing or annealing restored their good properties. The author has repeated these experiments, and finds that used rails break more easily, especially when the head is placed downwards. The worn surface often showed fine cracks, seldom deeper than 0·005 inch; but these could not be seen in rails which had been in use for a comparatively short time, and yet such rails broke easily when turned head downwards. In these rails the microscope shows a hardened layer or skin of metal, varying from 0·004 to 0·015 inch in thickness. Filing off the surface, or annealing if there are no cracks, makes the rails practically as good as new. Thin slices sawn from a rail section showed that the metal in the tread was brittle, and behaved like over-drawn steel wire, whilst the other slices preserved their strength and flexibility. When these cracks are present the cause of fracture is

\* *Journal of the West of Scotland Iron and Steel Institute*, vol. iv. pp. 23-25.

† *Ibid.*, vol. iv. pp. 25-36, with one plate.

obvious, and the hardened but uncracked skin is very liable to start cracks when bent by the passage of the wheels. In the surface slices it was noticed that the weak places occurred where there were dark red rust stains, which were deeper where the steel was most fragile. Microscopic examination of rails not showing surface cracks indicates that the steel has been dragged or forced forwards, and the weak lines appear as curves in the surface layer. The various actions of the locomotive and carriage wheels on the rails are then traced to account for the hard surface. At present the author is unable to explain the causes of cracks in some rails and not in others. One old locomotive tire was also examined, and found to be covered with small cracks. Some photographs are given, which show the cracks and the drag on the metal very clearly.

T. Andrews\* has made exhaustive microscopical, chemical, and physical examination of other rails of known age and conditions of service on some of the main lines of railway, and has had special opportunities of comparing the structure of old and new rails, and he has thus been able to obtain valuable and interesting information on some of the causes leading to the loss of strength in steel rails. The information acquired in course of these researches enables a specification to be formulated for modern steel rails calculated to promote both durability and safety in rail service. The difference between the loss of strength from mechanical abrasion and the deterioration of the ultimate crystalline structure of the metal under the fatigue of stress consequent on the presence of internal micro-flaws is shown. The effect of low temperature in reducing the impact resistance of rails, the influences of corrosion, and the manner in which vibratory stress induced microscopic internal growing flaws in rails are also demonstrated, and many illustrations are given of the deleterious manner in which sulphur and other impurities induce the fracture of rails. The influence of various kinds of ballast on the permanent way is also alluded to, and comparative illustrations from actual practice are given of this aspect of the subject. Numerous microscopic illustrations of the ultimate structure of old rails of long service compared with modern ones were shown, and the sources of weakness in rail structure demonstrated. The structure best calculated to yield the most durable and safest results was indicated. In conclusion, reference was made to the

\* Paper read before the Sheffield Society of Engineers and Metallurgists, through *Industries and Iron*, vol. xxii. p. 167; also paper in *Engineering*, vol. lxiii. pp. 266, 499, &c.

recently appointed Royal Commission on the loss of strength in steel rails, and the hope was expressed that after considering the practical and scientific evidence, the labours of that Commission would result in a general improvement in the quality and reliability of the steel rails of the future.

**The Magnetic Properties of Iron.**—Ebeling and Schmidt\* discuss the magnetic balance of Du Bois, which is extensively used in Germany for investigating the magnetic properties of iron and steel. The errors introduced into the permeability results by the earth's field are bound to be due to the vertical component only, and may be eliminated by superimposing the negative on the positive branch of the hysteresis curve and assuming the curve midway between the two as the true curve.

F. F. Martens † investigates the magnetic viscosity of samples of iron by cutting them in the shape of circular discs, which have the advantage over the thin rod in that they can be revolved. This is done in the earth's horizontal field. This shape lends itself to both the ballistic and the magnetometric method. The hysteresis loss is independent of the velocity of rotation within the limits of 2·5 and 200 per second. It is less in steel, nickel, and hard iron than in soft iron. The intensity of magnetisation depends distinctly on the rate of rotation, varying by 0·03 to 0·1 per cent. within the limits mentioned. When the rotating disc is suddenly stopped, the magnetisation slowly increases, reaching its maximum in two or three minutes.

Messrs. Oeking & Co.‡ publish details of tests of dynamo steel castings made by them, and these show that, as regards hysteresis, the unannealed metal gave better results than were obtained after annealing.

Tests made at the Physikalisch-Technische Reichsanstalt § have shown that, as regards its magnetic properties, ingot steel is but little behind the best quality of Swedish malleable iron, if properly annealed.

**Electric Properties.**—A. Campbell|| gives the results of some experiments made in soft metals by permanent stress. Amongst the tests some were made on iron wire and ferro-nickel wire subjected to stretching. Both German silver and soft iron remain of practically

\* *Zeitschrift für Instrumentenkunde*, through the *Electrician*, vol. xxxviii. p. 336.  
Wiedemann's *Annalen*, No. 1, through the *Electrician*, vol. xxxviii. p. 400.

† *Stahl und Eisen*, vol. xvi. p. 1006.                                   § *Ibid.*, p. 841.  
|| *Engineering*, vol. lxiii. pp. 468-469.

constant conductivity, which seems to show that, up to their breaking-points, they stretch out just as if they were liquids.

**The Alloys Research Committee.**—The fourth \* report by W. C. Roberts-Austen to the Alloys Research Committee deals especially with alloys in relation to their fusibility and strength, as brought to light by the consideration of eutectic alloys. Guthrie introduced this term to denote the most fusible alloy of two or more metals, comparing it to the mother-liquor of a salt solution. The recording pyrometer shows that, as regards alloys, the case is really far more complicated, and many alloys, when fluid, consist of more than one solution, and each on cooling leaves a solid deposit and a mother-liquor. The separation of an eutectic alloy is shown on the cooling curve by a break or bend. In a brass, or alloy of zinc and copper, such a point occurs, but disappears when iron is added to make the alloy into Aich's metal, and at the same time the metal becomes physically much stronger. Only those eutectics which are more fusible than the mass of the alloy are sources of weakness. The presence of eutectics, with comparatively high melting-points, usually increases the strength, although it diminishes the extensibility. The relations between melting-points, atomic volumes, and strength are also considered.

**Hardening Steel.**—During the past ten years the theory of hardening steel has been the object of numerous researches, but, owing to the large amount of work done in this field, it has become difficult for those who have not taken an active part in the investigations to keep pace with their progress. H. Le Chatelier † has consequently been induced to prepare a memoir on the present state of knowledge on this question.

**Evidence for the Allotropic Theory.**—H. M. Howe ‡ thinks that the increase in tenacity after quenching in certain specimens is too great to be accounted for by the small percentage of elements other than iron present in the metal, and he has made further experiments with a very pure iron containing only:—

Carbon.	Silicon.	Manganese.	Phosphorus.	Sulphur.	Copper.
0·04	trace	0·03	0·007	0·014	0·10

\* *Proceedings of the Institution of Mechanical Engineers*, 1897 (advance proof).

† *Revue Générale des Mines*, January 15, 1897.

‡ *Engineering and Mining Journal*, vol. lxii. p. 557.

The test-pieces, of which the test-results are given below, were all machined out of the same block. In order to show whether stress might have any effect, two transverse holes were bored through some of the specimens so as to remove the centre, leaving a small rectangle at each corner.

No.	Size in Inches.	Size of Holes Bored, Inches.	Tenacity, Lbs. per Sq. Inch.	Elastic Limit, Lbs. per Sq. Inch.	Elongation, per Cent. in 1 Inch.	Reduction of Area, per Cent.
6	0·162 by 0·174	...	48,580	23,050	44	72·3
10	0·187 " 0·204	0·083 and 0·082	49,890	...	...	...
2	0·176 " 0·181	...	52,040	30,400	43	77·8
9	0·183 " 0·198	...	67,400	42,820	28	58·56
3	0·177 " 0·186	0·073 and 0·074	70,690	...	...	...
7	0·178 " 0·197	0·086 " 0·085	60,190	...	...	...
8	0·179 " 0·195	0·087 " 0·088	62,450	...	...	...

Nos. 6 and 10 were cooled slowly from 930° C.; No. 2 quenched from 930° C. in water; and Nos. 9, 3, 7, 8 quenched from 930° C. in iced brine. The increase of strength due to quenching is very noticeable, and but little effect is produced by removing the centre. It is as difficult, says the author, to explain them by the effects of foreign elements or stress as it is easy to explain them by supposing the allotropic iron to exist and to be retained by rapid cooling.

This steel showed an increase of 39 per cent. in tenacity, and 86 per cent. in elastic limit by rapid cooling. In a further communication\* the author has found that in the form of wire the increase in tenacity is 132 per cent., and the elongation is lowered 63 per cent. In another experiment a quenched bar was turned down to remove the surface, and it was found that the core was even harder than the surface, the figures being:—

	Diameter.	Tensile Strength.	Elongation on 1 Inch.
Quenched bar before turning . .	Inch. 0·1717	Lbs. per Sq. Inch. 67,400	Per Cent. 28
Quenched bar after turning . .	0·112	72,400	18

The centre can cool less rapidly than the outside, but it is under greater stress, and this may cause the iron to be maintained in the allotropic state.

\* *Engineering and Mining Journal*, vol. lxiii. pp. 111-112.

**Fibre and Grain.**—Haedicke \* describes an experiment in which a piece of iron 1 inch square received in the cold state 15,600 somewhat heavy blows, turn and turn about on the opposite sides, at the same spot, until it broke of its own accord. The fracture appeared that of a fine-grained iron. Photographs are shown of this fracture, and of other fibrous fractures of the same piece. The action of the blows evidently went far beyond the limit of elasticity, and it was only under their influence that the fibre passed into a granular state. Provided the metal is not subjected to such excessive treatment, it does not change in this way. The specific gravity of the unhammered iron used in the above test was found to be 7·838, while the hammered metal had the specific gravity of 7·843.

**Influence of Temperature on Rolling.**—A. Martens † reports on the results of an examination made at the Imperial Testing Institute at Berlin on the influence which is exerted by the degree of temperature possessed by the metal during the rolling of rails made of basic Bessemer steel. For microscopic examination, a section was cut across each rail, well polished, and marked into twelve different divisions. A series of samples were treated in different ways: (1) rolled in the ordinary manner; (2) cooled before the two last passes to an extent which caused the edges of the flanges to be dull red, while the head was still at a bright red; while (3) a third set was so cooled before the two last passes that the edges of the flanges were scarcely even dark red, and the head at the commencement of the dark red temperature. These samples were subsequently examined both macroscopically and microscopically. Photographs were taken, and planimetric measurements were made.

As the result of this investigation, the author states that, leaving the rail-foot out of consideration, the effect of cooling was to diminish the proportional limit by from 10 to 20 per cent., to increase the limit of elasticity and the tensile strength by about 5 per cent., and to reduce the elongation by about 10 per cent., the reduction of area, especially of the head, diminishing by about the same percentage.

With regard to the effect exerted on the different portions of the rail section by the different temperatures, the proportional limit is higher in the case of the web than of the head, and the more so the colder was the temperature of the final rolling. The limit of elonga-

\* *Stahl und Eisen*, vol. xvii. p. 186, with three illustrations.

† *Ibid.*, pp. 51-55.

tion was the higher, the lower the temperature was in the final stage of the rolling, and was about 10 per cent. higher in the foot than in the head. The ultimate tensile strength shows a somewhat lower increase, amounting to about 5 per cent., both in the foot and in the web. The elongation increases largely in the rail-foot—up to 14 per cent. as compared with the head. The reduction of area increases by cold rolling in the web as compared with the metal of the rail-head.

Taking everything into consideration, the conclusion come to by the author is that the effect of cooling down before the last two passes is to slightly improve the mechanical properties of the rail, but it is as yet uncertain whether the rail will wear better in practice. How far the changes in the mechanical properties of the rail are due to changes in its texture is as yet not accurately determined, but in general the photographs tend to show the accuracy of the Sauveur rule that, with a diminishing size of the grain, both the tensile strength and the elongation increase.

**The Influence of a Blue Heat.**—A. Kurzwernhart \* observes that the deleterious effect observed after the mechanical treatment of iron at a blue heat has long been known, but that most possess but a general knowledge of the question. A boiler-plate manufactured at the Teplitz Works was returned by the purchasers as brittle, having shown cracks in the boiler-test. This gave rise to an investigation, which showed that the plate had been removed from the heating furnace at a very unequal temperature—red-hot on one side, and only brown-hot on the other. Further, that in rolling, the side which was only brown-hot to begin with, became quite black by the time the rolling was completed. This led the author to examine the whole of the plate carefully in its various parts, with a view to ascertain more completely the exact influence which had been exerted by the working of the plate at a blue heat. He wished to determine, that is, the limits of temperature at which such an influence is or is not exhibited; and, further, to ascertain the temperature limits within which the influence exerted by working the plate at a critical temperature could be eliminated. Other experiments were made with a view to ascertain whether an already damaged plate broke more readily on bending cold, or when bent at a critical temperature.

The plate itself was 0·89 inch in thickness. It had been bent, and had numerous cracks at the edge on one side, about 8 inches in length,

\* *Stahl und Eisen*, vol. xvi. pp. 849-857, with fifty-nine illustrations.

whilst the other side showed none. A superficial examination by bending showed the plate to be very brittle on the side where the above-mentioned cracks were observable, whilst the other side was tough. Analysis showed the plate to contain per cent. :—

Carbon.	Manganese.	Phosphorus.
0·061	0·21	0·022

The chemical composition of the plate was therefore directly opposed to its brittle character. Bending tests were made, and then the material was submitted to tensile tests. These latter showed, longitudinally :—

	Limit of Elasticity.	Tensile Strength.	Elongation.	Reduction of Area.
	Tons per Sq. Inch.	Tons per Sq. Inch.	Per Cent.	Per Cent.
As returned . . .	18·16	25·84	20·50	56·5
After annealing . . .	16·00	23·49	31·25	60·3

As the plate left the Teplitz Works after having been annealed, there can be no doubt but that the increased strength and brittleness of the plate as returned was due to its having been worked at the critical temperature. A long series of tests were then made, and the author gives sketches illustrative of fifty-six test-pieces after treatment, these test-pieces having been differently treated.

It was found that not only was the "blue heat" dangerous, but that working the metal at certain other temperatures was also dangerous.

The most dangerous temperature was found to be that at which on heating the metal assumes a light-yellowish surface coloration. Experiments as to the influence exerted by bending at various temperatures gave results which showed this to be the case. How greatly the character of the metal varies is evident from the following tests of samples in which the annealed and straightened plate was bent before testing to a radius of 0·5 metre :—

Temperature.	Limit of Elasticity.	Tensile Strength.	Elongation.	Reduction of Area.
	Tons per Sq. Inch.	Tons per Sq. Inch.	Per Cent.	Per Cent.
Light yellow coloration	26·48	30·28	15·25	54·7
Brouze coloration . . .	23·49	27·94	..	53·7
Violet coloration . . .	24·19	28·25	19·00	54·7
Red-hot . . . . .	18·98	24·25	28·00	61·8
Cold . . . . .	16·82	24·25	25·50	61·0
The annealed metal showed . . . }	16·00	23·49	31·25	60·3

The results further show that bending backwards and forwards when the metal is either cold or red-hot exerts no appreciable influence as regards the tensile tests when metal so treated is compared with annealed metal. Ten light blows with a hammer at the critical temperature were apparently without effect. Other tests showed that by heating the metal that had been rendered brittle to a red temperature so dull that it could only be distinguished in a darkened place, the brittleness was eliminated, and the metal again became tough. A variety of other tests were made, both with the metal of the plate already referred to, and with a sample of ingot metal containing—

Carbon. 0·12	Manganese. 0·34	Phosphorus. 0·058
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A weld iron having the composition—

Carbon. 0·31	Manganese. 0·20	Phosphorus. 0·021	Silicon. 0·10	Sulphur. 0·016
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was also examined.

Bending at the critical temperature was found to be dangerous in the case of the weld iron also, as well as when ingot metal was so treated. The cold samples of metal gave, in the case of the weld iron, the following results :—

After Treatment at the Temperature of	Limit of Elasticity.	Tensile Strength.		Elongation.	Reduction of Area.
		Tons per Sq. Inch.	Tons per Sq. Inch.		
The yellow coloration	18·54	27·17	16·4	9·5	
The blue coloration .	21·27	26·22	23·9	12·0	
Cold . . . .	14·54	24·00	35·2	21·5	
Annealed and unbent	15·56	22·92	30·1	25·0	

**The Effect of Temperature.**—R. C. Carpenter \* gives the results of a few experiments on the effect of temperature on the strength of wrought iron and steel. The test-piece was heated by surrounding it with a block of cast iron made in two parts and kept hot by Bunsen burners. The results are plotted as curves, and show a maximum strength between 400° and 550° F. G. C. Henning gives curves showing the results obtained by Rudeloff.†

H. K. Landis ‡ shortly summarises the results obtained by different experimenters who have made researches into the effect of cold on the strength of iron and steel. These indicate that as the temperature

\* *Transactions of the American Society of Mechanical Engineers*, vol. xvii. pp. 198-211.

† *Journal of the Iron and Steel Institute*, 1896, No. I. p. 496.

‡ *Iron Age*, vol. lviii. pp. 673-674.

falls the elastic limit and the ultimate strength are increased while the elongation is diminished. Cold has the same effect on acid and basic iron, but proportionately greater on puddled iron. As regards falling-weight tests, cold makes itself particularly felt when defects are present, but the effect diminishes when the iron is well worked. Cold seems to produce analogous results to those obtained in cold-drawing wire or tube, that is, the metal is under the influence of internal strains, which, however, disappear upon its regaining a normal temperature.

**Residual Stresses in Steel.**—H. K. Landis \* discusses the causes of residual stresses in steel to which so much importance is now attached. In castings these arise from the solidification and contraction of the external part before the interior has settled down, and they similarly occur from the greater compression of the outside in wire-drawing, cold-rolling, drawing, forging, stamping, &c. The endurance tests made on rotating shafts at Watertown are referred to. Even in hot-rolled or worked metal these residual stresses may occur, partly from the action of the working on the surface and partly from the difference of the internal and external temperatures.

**Testing-Machines.**—G. C. Henning † describes a mirror apparatus for minute measurements of change of length, and a pocket recorder for stress-strain diagrams. In the first apparatus, which is used for laboratory purposes only, two mirrors are attached to spindles carried by knife-edges bearing against the test-bar to be strained; scales are mounted at a given distance from the mirrors, and their reflections are read in a telescope. The construction of this appliance is illustrated, but the recorder is only described. It is a modification of the Tabor indicator, arranged so as to be portable, and to give an automatic record.

G. W. Bissell ‡ describes and illustrates an autographic recorder attached to a 50,000-lb. Olsen testing-machine, and arranged for transverse or punching tests, where the movement of the head may be taken as equal to the deformation of the test-piece. A paper-carrying drum is rotated by connection to the beam, and the pencil carriage is moved across it by connections to the head of the machine.

M. A. Howe § describes a new 50-ton multiple lever-testing machine for beams and framed structures built for the Rose Polytechnic Institute

\* *American Manufacturer*, vol. lix. pp. 908-909.

+ *Proceedings of the Engineers' Club of Philadelphia*, vol. xiii. pp. 338-345.

‡ *Transactions of the American Society of Mechanical Engineers*, vol. xvii. pp. 76-80.

§ *Digest of Physical Tests*, vol. ii. pp. 180-186.

in Indiana. Cross-breaking tests on pieces 20 feet long can be made and columns 6 feet long can be tested. A double stirrup suspension was designed for the support of long pieces, so as to place the end knife-edges in the neutral plane of the specimen. The framing is largely built of wood, and the total cost is given as under £100.

Illustrations have been published \* of a 100,000-lb. Emery testing-machine, used for testing bicycle tubing and material.

A paper on "The Mechanical Testing of Iron and Steel" † deals mainly with the practical side of testing, and states that the first testing-machine was for testing chain cables, and capable of pulling 100 tons. This machine was made in 1812, but the first really good testing-machine was made by Mr. Williams, manager of an ironworks in South Wales in 1829. The Admiralty, in 1831, not willing to trust to chain-makers' tests, put down a machine of their own. This was the parent of all English modern testing-machines, and all the older machines contained all the essential points of modern types. The maximum length of all German machines was 30 feet, and the largest testing-machine in the world was at the Watertown Arsenal, in the United States. That machine broke metal under a stress of 750 tons, though in all English testing-machines accuracy and sensitiveness were sufficient for scientific testing. Several testing-machines in use were described. Transverse tests in foundries were perfectly satisfactory, and there was no excuse for any one not testing cast iron. Testing had done a great deal to produce a given material.

An illustration has appeared of a milling-machine for rapidly preparing test-pieces. Twenty-four sheared strips,  $\frac{1}{2}$  by 18 by 3 inches wide, were cut down to  $1\frac{1}{2}$  inch in twenty-five minutes. Spiral milling cutters are brought against both edges of the piece, which is moved forward by a carriage, and the cutters are moved in and out, so as to leave the holding shoulders on the test-piece. ‡

**Standardising the Testing of Iron and Steel.**—P. Kreutz-pointner § again urges the necessity for standardising the testing of iron and steel. The very many different methods of testing called for by various engineers are commented upon to show the variable quality of metal used for similar purposes, and the different results obtained from

\* *Iron Age*, vol. lix. No. 2, pp. 1-3.

† Paper read before the South Staffordshire Institute of Iron and Steel Works Managers, through *Industries and Iron*, vol. xxii. p. 215.

‡ *Digest of Physical Tests*, vol. ii. pp. 128-129.

§ *Engineering Magazine*, vol. xii. pp. 755-764, 977-982, with illustrations.

the same material by altering the dimensions of the test-piece are especially dwelt upon. It is concluded that the test-piece should be as large as possible and that standard methods should be prescribed, but at the same time it is not necessary for hard and fast lines to be laid down, but only within certain narrow limits the same length, width, or diameter and shape should be used, as well as nearly uniform speed.

The reports of the French committee on methods of testing are extracted by M. Martel,\* who gives more or less fully those parts which are of interest to the artillery and naval services.

**Testing Cast Iron.**—T. D. West† points out that the test-bar does not give the actual strength, chill, or contraction of a casting, but it gives a convenient basis for comparison in making future castings, and it also affords a record. To properly fulfil this duty, all test-bars should be made of uniform size, and the results of different bars cannot be compared, for the formulæ proposed differ as much as the results. The analyses of each sample are also appended.

The author has previously contended for the adoption of the  $1\frac{1}{8}$  inch round bar as a standard, but he now thinks that  $1\frac{1}{8}$  and  $1\frac{1}{16}$  bars are best utilised for iron containing less than 1 per cent. of silicon and over 0·04 sulphur. Whatever is done, however, one size of bar should always be adhered to, but it would be still more advantageous to cast all three sizes and append to the tests the full chemical analysis as a basis for future reference. The tests and analyses of six varieties of iron are given, and as an example the first of these is given below:—

#### Chill Roll Iron.

Diameter in Inch.	Breaking Load.		Area.	Strength per Square Inch.	Deflection.
	Lbs.	Square Inches.			
$1\frac{1}{8}$ (1·140)	3,250	1·021		3,183	0·015
$1\frac{1}{8}$ (1·655)	9,600	2·151		4,417	0·090
$1\frac{1}{16}$ (1·968)	15,250	3·042		5,013	0·085
Si.	S.	Mn.	P.	Combined Carbon.	Graphitic Carbon.
0·84	0·071	0·285	0·547	0·61	2·45
					Total Carbon.
					3·06

\* *Les Essais des Métaux en 1893*, being an extract from the *Mémorial de l'Artillerie de la Marine*, 1896. A copy has been presented to the Library of the Institute. The leading points have been given in the *Journal of the Iron and Steel Institute*, 1896, No. I. p. 503.

† Paper read before the Foundrymen's Association, through the *Iron Trade Review*, vol. xxix. No. 50, pp. 14-16; *Iron Age*, vol. lviii. pp. 1137-1138.

In discussing \* this paper, one member, Prince, thought that the author was making strong statements from insufficient data, and that, like W. J. Keep, he generalised too widely from one experiment. The best size of the bar, it was remarked, seemed to be in a very unsettled state.

W. J. Keep † gives the results of tests of various sizes of test-bars made in 1894 from different mixtures of cast iron, for the Committee of the American Society of Mechanical Engineers on methods of testing. Amongst the points treated are the chemical composition, slight variations in the size of the test-bars, the dimensions of the bars and their form, strength, and shrinkage. Numerous curves are given to illustrate the tests, of which the numerical results are given in an appendix consisting of thirty-two tables.

J. Christie ‡ advocates the drop-test for cast iron as being the simplest and on the whole the most satisfactory. All that is required is a bed-plate with supports, guides, lifting and releasing gear for the tup, and a pencil attachment to the tup may record the deflection. For specimens one inch square and twelve inches between supports, a weight of 200 lbs. falls approximately 3 inches to break ordinary cast iron.

**Tests of Foundry Irons.**—A. B. Harrison § describes a number of "freaks" of foundry iron, and for this purpose analyses of a number of different irons are given, together with their tensile and transverse strengths. The methods of making the test-pieces and the tests are also given. The table below shows a selection of those given; the first three show unexpected percentages of silicon and sulphur, and the latter two of phosphorus :—

Si.	S.	P.	Mn.	Graphite.	Combined Carbon.	Tensile Strength.	Transverse Strength.
Per Cent.	Lbs. per sq. in.	Lbs. per sq. in.					
3·20	0·005	0·54	0·88	3·60	0·06	15,280	2500
3·50	0·090	0·54	0·80	3·60	0·06	23,450	3000
3·05	0·008	0·53	0·71	3·60	0·12	39,170	3000
2·40	0·018	1·01	0·58	3·50	0·10	20,760	2280
2·50	0·019	0·41	0·65	3·25	0·10	20,910	2850

\* *Iron Age*, vol. lviii. pp. 1137-1138.

† *Transactions of the American Society of Mechanical Engineers*, vol. xvii. pp. 674-729.

‡ Paper read before the Foundrymen's Association, through the *Iron Age*, vol. lix. No. 6, pp. 4-5.

§ Paper read before the Western Pennsylvania Central Mining Institute, through the *American Manufacturer*, vol. lx. p. 44.

Another set are given to show uniform shrinkage with very different compositions. The after treatment of test-bars is then referred to in reference to the effect of tumbling. Two test-pieces were cast from the same gate, and one was tumbled. Out of twelve pairs of tensile tests, one showed no effect, five showed an increase, and six a decrease of strength, due to tumbling. Nine transverse tests showed an increase. Other transverse tests of pieces cast on the side showed greater strength with the drag side uppermost, but this disappeared after tumbling. The use of analysis is also mentioned.

In the discussion\* it was shown that whilst hot-poured bars are stronger than cold-poured ones, the latter show a greater increase of strength after tumbling.

G. R. Johnstone † gives, in seventeen tables, the results of over 300 physical tests, and 1000 analyses of cast iron made at Embreville, Tennessee. The tables are arranged to show the effect on the tensile and transverse strengths, drop tests, chill and fracture of each element with the other elements constant. The effect of each element is also discussed.

**The Products of the Dnieproffsky Steelworks.**—The following are analyses and tensile tests of the products made at this South Russian steelworks, which is provided with both a Bessemer and an open-hearth plant : ‡—

#### Bessemer Metal.

	C.	Mn.	Si.	S.	P.	Tensile Strength.	Elongation.
Ingot iron, No. I . . {	Per Cent.	Tons per Sq. Inch.	Per Cent.				
	0·08	0·4	trace	0·03	0·03	26·7	26 to 18
	to	to	to	to	to	30·5	
Mild steel . . {	0·15	0·6	0·05	0·06	0·06	30·5	22 , , 15
	to	to	to	to	to	to	
	0·25	0·8	0·05	0·08	0·08	34·9	
Medium hard steel . . {	0·25	0·06	0·03	0·03§	0·04	34·9	20 , , 15
	to	to	to	to	to	to	
	0·35	1·00	0·10	0·01	0·08	41·3	

\* *Iron Trade Review*, vol. xxx. No. 4, p. 9.

† Paper read before the Foundrymen's Association, through the *Iron Age*, vol. xli. No. 10, pp. 5-8.

‡ *Stahl und Eisen*, vol. xvi. p. 864.

§ As in original.

The ingot iron cannot be hardened. It is used for wire, bridge material, and ship plates. The mild steel is used for beams and axles, and the medium hard steel for tyres and rails.

*Basic Open-Hearth Metal.*

	C.	Mn.	Si.	S.	P.	Tensile Strength. Tons per Sq. Inch.	Elongation. Per Cent.
Ingot iron, soft, brand 4 M . . .	0·08	0·3	Per Cent.	0·02	Per Cent.	19·0	35 to 28
	to	to	traces	to	traces	to	
	0·15	0·5		(0·05)		21·6	
Ingot iron, soft, brand 3 M . . .	0·08	0·4	0·05	0·04	traces	21·6	32 , , 25
	to	to	to	to	to	to	
	0·12	0·6	0·10	0·08	0·04	25·4	
Ingot iron, soft, brand 1 M . . .	0·12	0·60	0·05	0·04	traces	25·4	25 , , 20
	to	to	to	to	to	to	
	0·20	0·80	0·10	0·08	0·04	31·8	
Mild steel, brand 1 M	0·20	0·60	0·06	0·04	traces	31·8	20 , , 15
	to	to	to	to	to	to	
	0·30	0·80	0·15	0·08	0·04	38·1	
Medium hard steel, brand P . . .	0·30	0·60	0·06	0·04	traces	38·1	15 , , 10
	to	to	to	to	to	50·8	
	0·50	1·00	0·10	0·08	0·04		

The three ingot irons cannot be hardened. Brand 4 M is used for pipes, rivets, and sheets ; brand 3 M for boiler-plate, universal iron, and bridge material ; brand 1 M for reservoir plates and bearers. Brand 1 M, soft steel, is used for bearers, axles, and rails ; and mark P steel for rails, tyres, and springs.

**Elastic Limit or Yield-Point.**—P. Kreuzpointer \* discusses the value of the elastic limit as a fiducial point. The reduction of area cannot be measured exactly, and it only implies local defects, whilst the elongation can be measured accurately if care be taken. But the elastic limit cannot be determined with accuracy ; indeed, there is no agreement as to what is meant by the point. Further, by properly handling the test-piece the elastic limit may be raised or lowered as desired. In the report of the French Commission † three distinct periods of the limit of elasticity are recognised, and the author interprets these as follows :—

(a.) The limit of elasticity, E, is the greatest load per square millimetre for a given area which does not produce permanent set after the

\* *Iron Age*, vol. lix. No. 3, pp. 8-9, No. 5, pp. 5-7.

† *Journal of the Iron and Steel Institute*, 1896, No. I. p. 503.

application of the load, the metal resuming its original form after at least fifteen minutes to within  $\frac{1}{1000}$ th millimetre in 8 inches.

(b.) The limit of proportionality, P, is that point when the load per square millimetre produces a stretch proportionate to the load with an accuracy of  $\frac{1}{1000}$ th millimetre in 8 inches with an increase of load of 1 kilogramme per square millimetre.

(c.) The visible limit of elasticity is the one where the original load per square millimetre produces a visible stretch without a noticeable increase of load. This point shows itself by the drop of the beam of the testing-machine or the pressure-gauge.

Results obtained by the author show the yield-point or drop of the beam much higher than the elastic limit obtained by measurement; but the most accurate data are obtained by Bauschinger, who, in some examples selected at random, shows an average difference of over 6700 lbs. in iron and nearly 5000 lbs. in Bessemer steel. This may give a difference of 5 to 20 per cent. in the safety of structural steel. Now the yield-point, or Bauschinger's *Streckgrenze*, is sometimes so slight that the tester misses it, or mistakes a wavering of the beam for the drop, or even takes the rapid stretch which sometimes occurs at higher points for this limit.

The study of the structure of steel may cast some light on this behaviour. All cast steel may be considered as a mass of crystals set in a matrix. When they are approximately of the same hardness, a "mushy" steel is obtained with low elasticity and strength giving maximum contraction, and an excessive percentage elongation in a short section. With hard crystals and a soft matrix a better-resisting metal is obtained, with less local contraction and a greater staying power. Possibly this behaviour is due to the flow of the molecules, which at certain points will not move freely. In fact, several such points may sometimes be observed in testing. The author also considers the behaviour of the crystals themselves from this point of view of flowing movement, and considers the elastic limit above mentioned as E as the elastic limit of the crystals themselves. The limit of proportionality occurs when the crystals begin to move out of place, and then when they lose their natural positions the yield-point takes place. Some illustrations are given of test-pieces on which lines have been drawn with dividers at each application of 1000 lbs. of load. The distance apart of these lines shows the stretch, and the varying distances indicate the elastic limit and the yield-point, besides showing the apparent stiffening or regaining of strength at intervals, which may be

ascribed to the temporary choking of the flow of molecules. Altogether the author is in favour of the limit of proportionality as the proper elastic limit for the engineer.

### The Strength of Chilled Iron as affected by Stress and Chill.

—A. W. Whitney \* discusses the transverse strength of chilled iron as affected by the relative directions of stress and chill. Tests were made with cast iron suitable for good car-wheels, and showed wide differences between duplicate bars when broken by stress at right angles to lines of chill, and when broken by stress in the same direction as lines of chill, greatly in favour of the latter. This was also found in other than chilled castings when the direction of the most rapid dissipation of heat was taken into account. Experiments were also made to determine whether rumbling had any effect, but uniform white iron is little affected, if at all, and certain strong very homogeneous grey compositions gain less in rumbling than ordinary mixtures similarly cast. It was also proved possible to cast a high chilling iron in such form as to have nearly or quite the same modulus of rupture, whether cast in sand, so as to be totally grey, or cast of the same volume between chills, giving a test-bar of a less depth, so as to be totally white. The author was led to adopt a form of test-bar 1½-inch deep and 2½ inches wide, the narrow sides being cast against sand and the wide sides against chills. The lines or crystals of chill form parallel lines, and meet at the neutral axis. Square and hexagon bars were also used, the latter being preferable, and the results compared by Johnson's formula. The chill and contraction tests are also specified.

A number of results are presented in tabular form, the modulus of elasticity being given for the sake of comparison. Square bars in one instance broke across the chill at 4000 to 6000 lbs., and in the direction of the chill at 9000 to 11,000 lbs. Crushing and tensile tests apparently give similar results.

**Steel Specifications.**—H. H. Campbell † gives some general suggestions on specifications for structural steel. The amount of phosphorus should be limited, and should be determined by analysis. In fact, tests are not regarded as of value in connection with this element. Except as regards rivets, eye-bars, and flange steel for boilers, the

\* Paper read before the Foundrymen's Association through the *Iron Trade Review*, vol. xxx. No. 2, pp. 13-15; *Iron Age*, vol. lix. No. 8, pp. 12-13; *Journal of the Franklin Institute*, vol. cxliii. pp. 267-278.

† *Proceedings of the Engineers' Club of Philadelphia*, vol. xiii. pp. 308-312.

engineer need not specify for sulphur, as it only affects the red-shortness. A larger range for the ultimate tensile strength should be given, and also proportional figures for the elastic limit. The figures prescribed should also bear some relation to the size of the finished work, and due regard ought to be paid to the effect of annealing. Segregation must be taken into account, and it should be considered that the test is taken in the ordinary way, so as to allow for the most segregated part.

H. K. Landis \* thinks that specifications should always indicate the purpose for which the steel is intended, and that it is not sufficient to merely prescribe the physical and chemical tests for the material. It is pointed out that tensile tests do not indicate what the metal is capable of enduring under shearing or impact stresses, and further, the tensile strength is sometimes increased by residual strains. Test specimens should be taken from the piece in conformity with the direction of the stresses it will undergo in practice, and not indiscriminately, as is often the case. Tension requirements should be specified, not as final, but simply as a check, and the first test should be on the finished piece as far as possible.

G. Giorgis and U. Alvisi † have analysed a number of specimens of mild steel, the mechanical properties of which have been studied by Biadego.

**Structural Steel Tests.**—J. Christie ‡ shows that steel under dynamic stress yields progressively, and the advantage does not always rest with mild steel. Tensile tests do not show sufficiently the capacity to endure these stresses long, and need to be supplemented by other tests which recognise kinetic stresses, and the effect of shock and vibration. In fact, the tests should to some degree correspond with the work to which the steel is to be applied, and higher carbon steel may be advocated.

Professor Mehrtens § observes that test-pieces taken from old iron bridges indicate that the metal of beams which have been in use for thirty or forty years shows no marked diminution in its mechanical properties. Whole beams have sometimes been tested, and the author discusses this subject generally, and also treats of the arrangements of the testing laboratory.

\* *American Manufacturer*, vol. ix. pp. 11-12.

† *Gazzetta*, vol. xxvi. pp. 167-178.

‡ *Proceedings of the Engineers' Club of Philadelphia*, vol. xiii. pp. 327-333.

§ *Stahl und Eisen*, vol. xvi. pp. 712-714.

**The Use of Higher Carbon Steel for Structural Work.**—F. H. Lewis \* seeks to show that it is time to reopen the question of the use of higher carbon steel in structural work. In the early days, when the consumption of steel was on a much smaller scale, the methods of working the material were not so well understood, and in consequence there were more failures in working the harder steels. In spite of this, several of the largest bridges were built with steel having a strength of 80,000 lbs. The relative sizes of Bessemer and open-hearth works and the steel rail industry have had also great influence on the question. Now, however, harder steels of uniform quality can be made, their working is understood, and very numerous experiments have shown that they are amply trustworthy for any work required of them.

E. C. Shankland † deals generally with steel skeleton construction in the United States, and gives as the unit stresses commonly employed 16,000 lbs. per square inch fibre strain in steel H-girders, 15,000 lbs. in plate-girders and short columns in compression. Maximum stresses in columns are brought below 25,000 lbs.

H. K. Landis ‡ deals with the effect of the carbon content on the endurance of steel. Repeated stresses below the elastic limit will not cause failure nearly so quickly as when the stresses are above this limit. The tensile strength is not to be depended upon like the elastic limit in determining the value of steel. By increasing the carbon the elastic limit, and consequently the endurance, is raised.

**Steel for Bridge Pins.**—According to A. C. Cunningham, § tests of finished bridge pins is now an established though not a popular custom. They are made either by rolling or forging, according as their diameter is below or above about 6 inches. As a rule, when rolled, they are finished too hot; and in both rolled and forged pins the metal is not sufficiently worked, so that the interior is greatly inferior to the exterior in regard to the strength of the metal. Medium hard steel of 70,000 lbs. tensile strength gives the best results, and the pins are improved by annealing. A number of tests are given, and a specification is proposed. This directs

\* *Stahl und Eisen*, vol. xvi. pp. 321-326.

† *Minutes of Proceedings of the Institution of Civil Engineers*, vol. cxxviii. pp. 1-57.

‡ *Iron Trade Review*, vol. xxx. No. 1, p. 11.

§ *Transactions of the American Society of Civil Engineers*, vol. xxxvi. pp. 91-101.

that open-hearth steel shall be used with the following chemical limits :—

	Phosphorus.	Sulphur.	Manganese.
Acid steel . . .	not over 0·06	not over 0·03	between 0·5 and 0·8
Basic steel . . .	, 0·03	, 0·03	, 0·5 , 0·8

The smallest diameter of the ingot must be 50 per cent. greater than that of the finished pin. Pins are to be marked and annealed from a dark red heat for twenty-four hours. Tensile tests of not less than  $\frac{1}{4}$ -inch square bars cut from the exterior must show 60,000 to 70,000 lbs. strength, with elongation of 20 per cent. on 8 inches, and contraction of not less than 40 per cent. Tests cut from the centre may be 5000 lbs. less and 5 per cent. less in reduction of area. Analyses from the exterior and interior must not exceed the above limits by more than 10 and 50 per cent. respectively. W. Metcalf gives the sizes of hammers that should be used, and prefers to anneal from about 1100° F.

**High Carbon Steel for Forgings.**—A. L. Colby \* gives some notes on the practicability of using high carbon steels for forgings. For marine shafting steel is called for with a tensile strength of 80,000 lbs., elastic limit 50,000 lbs., and elongation of 25 per cent. in four diameters. These requirements are met by steel with 0·30 per cent. of carbon and  $3\frac{1}{2}$  per cent. of nickel. For locomotive crank-pins, steel is used with an elastic limit of 40,000 to 45,000 lbs., and containing—

Carbon.	Manganese.	Phosphorus and Sulphur.	Silicon.
0·40 to 0·45	0·60 to 0·70	0·030	0·10 to 0·18

Piston-rods for steam-hammers have been made of much harder steel than formerly with success, and two analyses of such steel were as follows :—

	Carbon.	Manganese.	Phosphorus.	Sulphur.	Silicon.
A. . .	0·55	0·74	0·024	0·030	0·181
B. . .	0·46	0·63	0·021	0·026	0·155

Tests of them were as follows :—

	Tensile Strength. Lbs. per Sq. In.	Elastic Limit. Lbs. per Sq. In.	Elongation. Lbs. per Sq. In.	Contraction. Per Cent.
A. . .	108,390	53,980	17·10	28·76
B. . .	88,970	50,100	22·85	47·07

\* *Proceedings of the Engineers' Club of Philadelphia*, vol. xiii. pp. 333-338.

Where high duty is required from a forging, mild steel of 60,000 lbs., tensile strength is not the best material to use. Harder steel, oil tempered if practicable, should be employed. In order to successfully temper a large forging, especially if cylindrical in shape, it is necessary to provide it with an axial hole throughout its length. In case oil-tempering is not practicable, a softer, tougher steel with 3 to 4 per cent. of nickel may be used, as the nickel increases the ratio of tensile strength to elastic limit and adds to the ductility. The following table shows what may be obtained :—

Test-pieces 2 Inches long, ½ Inch Diameter.	Mild Steel Annealed.	Medium Hard Steel Annealed.	Medium Hard Steel Oil-tempered.	Medium Hard Nickel Steel Annealed.	Medium Hard Nickel Steel Oil-tempered.
Tensile strength, lbs. .	63,000	80,000	90,000	85,000	93,000
Elastic limit, lbs. .	30,000	37,500	48,000	50,000	60,000
Elongation, per cent. .	28	23	23	25	25
Contraction, per cent. .	50	40	50	50	60

**Steel Failures.**—A. L. Colby \* shows that the failure of steel is more often due to faulty mechanical treatment than to the presence of rare elements. In forged and rolled material failures are often due to the use of insufficiently-worked metal, or to indifferent heat-treatment or lack of annealing. In spite of this, they are often ascribed to the presence of some small percentage of an element not usually associated with steel. Copper, titanium, and arsenic have thus been made scapegoats, in spite of some difficulty in determining exactly how much is present and what their real effects are. Oxygen is especially noteworthy in this connection, for the methods of its determination are very difficult to carry out with any pretence to accuracy. Hasty conclusions drawn from the supposed occurrence of these small percentages are therefore to be deprecated, and the cause of failure should rather be sought for in the mechanical treatment.

**Copper in Steel.**—A. L. Colby † gives a number of full analyses of different classes of steel to show that copper does not segregate, and has no deleterious effect. Steel with 0·067 to 0·306 per cent. was drawn into wire without showing red-shortness, with 0·055 to 0·360 was rolled into plates and drawn down into cups without cracking, and with 0·292 to 0·486 was rolled without roughness.

\* *Proceedings of the Engineers' Club of Philadelphia*, vol. xiii. pp. 312-321.

† *Ibid.*, pp. 312-321.

**Wire Ropes.**—S. Diescher,\* in an account of inclined planes, finds that the best results for wear and strength were obtained with ropes made of crucible steel wire of an ultimate tensile strength between 160,000 and 170,000 lbs. per square inch of section, and a 4 per cent. elongation in 12 inches between jaws of testing-machine. Three sizes of wire used in each rope showed as follows on the average:—

Diameter.	Tensile Strength.	Elongation in 12 Inches.	Twists in 8 Inches.
Inch. 0·109	Lbs. per Sq. Inch. 171,700	Per Cent. 4·2	22·4
0·134	176,300	4·6	16·0
0·148	177,700	4·7	15·0

Six, seven, and six of these wires respectively were used in each strand of a six-strand rope, which should give a total tensile strength of 245,000 lbs., allowing 10 per cent. reduction of strength for the finished rope. Actually it broke at 222,000 lbs., but this is explained by the inefficient grip in the testing-machine. Three of these ropes were in use for three, four, and five years respectively, the last one being still in service after 51,000 miles travel. The various strands of one rope were tested separately after it was worn out, and showed strengths ranging from 108,000 lbs. down to 27,000 lbs. The core wire seldom breaks, but its section is generally distorted.

**Wrought Iron and Steel.**—J. B. Johnson † deals with the use of wrought iron and steel, and recommends that for railway rolling stock the latter should be used where it has not to be forged or welded. There is no better material than the best grades of wrought iron, but they are too expensive for use for most purposes. As regards cheap wrought iron and mild steel of about the same price, the steel is so far superior as to stop all competition when the facts are known. It is important, however, to purchase all such material under good specifications and careful inspection to obtain full value for money. The fracture of wrought iron is dealt with in the course of the paper, and it is shown that its ordinary appearance is fibrous, yet under cer-

\* Paper read before the Society of Engineers of Western Pennsylvania, through the *Iron Age*, vol. lviii. pp. 1143-1144.

† Paper read before the St. Louis Railway Club, through the *Iron Trade Review*, vol. xxix. No. 53, pp. 14-15.

tain circumstances it may be crystalline. These are sudden fracture, admixture of steel in the faggot or pile, imperfect conversion leaving cast iron in the bloom, and over-conversion or burning.

**Boiler and Firebox Steel.**—T. L. Condron\* gives in graphic form, for the sake of comparison, the specifications of a number of railways, locomotive works, and steel manufacturers for boiler and firebox steel. A fair number of these conform to the specifications proposed as standard by the Master Mechanics' Association and the Steel Manufacturers' Association. The divergencies both in the chemical and physical requirements are commented upon, and the elastic limit is somewhat strongly condemned. All the specifications omit reference to this property, and some diagrams are given to show how widely various observers may differ in deciding what was to be regarded as the value of the elastic limit.

Barba † advocates the use of cast steel for building locomotives, and shows its advantage over wrought iron for wheel centres, crossheads, and other parts, and especially for the heavy built-up forged frames which demand so much labour and machining. The following are tests of steels made at the Midvale Steelworks for wheel centres, crossheads, domes, pistons, straps, &c. :—

Tensile Strength.	Elastic Limit.	Elongation.	Contraction.
Lbs. per Sq. Inch.	Lbs. per Sq. Inch.	Per Cent.	Per Cent.
61,500	29,500	32·8	54·1
69,500	34,500	22·9	30·9
70,000	36,000	31·6	48·2
79,430	38,190	23·8	30·1

A comparison is then drawn between cast steel and cast iron, in view of the strength and lightness obtained, and the fact that the former yields slowly instead of breaking suddenly. Other papers on kindred subjects were also read.

The use of steel for locomotive fireboxes is dealt with in *Stahl und Eisen*. ‡ Various reports on the subject from 1893 are considered, including a communication from P. Kreuzpointner, § of Altoona, who

\* Paper read before the Western Society of Engineers, through the *Engineering News*, vol. xxxvii. pp. 44-45.

† Paper read before the New England Railroad Club, through the *American Manufacturer*, vol. lix. p. 911.

‡ Vol. xvii. pp. 165-174.

§ *Ibid.*

deals with the results obtained in connection with the 3200 locomotives belonging to the Pennsylvania Railway, and shows that the use of ingot metal for boilers and fireboxes has given satisfaction. At the present time all the United States railways and manufacturers of stationary engines employ exclusively ingot metal of a tensile strength varying from 24 to 29 tons per square inch. A short time ago an inquiry was addressed to a very large plate-mill renowned for the excellence of its weld iron boiler-plates, asking how far ingot metal had affected the demand for weld iron plates. They replied that while ten years ago there was an active demand for the latter, it had now ceased, and that the sole business still done with this related to the repairs of old boilers and mud drums. Mr. Kreuzpointner draws attention to the fact, that while in the United States such excellent results have followed the use of ingot metal, the very opposite result has been experienced on the Prussian State Railways in connection with its use for fireboxes. He thinks this must be due to one of three causes. Either German manufacturers do not know how to produce the right material, which is scarcely credible, or the mode of construction of the boilers and fireboxes and their subsequent treatment in the shops is so faulty that even the best material is rendered valueless, or there must be a strong antagonism on the part of the authorities to this new material and an unwillingness to study the peculiarities of ingot metal in practice; and in this connection he remembers that six years ago it was stated that should ingot metal be used experimentally for fireboxes on the Prussian State Railways it was certain to be a failure. Numerous factors have to be considered if the use of the metal is to prove a success. In the first place, it must not be too hard. Experience has shown that the best metal is one having a tensile strength of from 24·5 to 29·5 or 30·35 tons per square inch, and an elongation of about 24 per cent. on 8 inches. On the Pennsylvania Railway the tensile strength must not exceed 29·5 tons unless the elongation amounts to 26 per cent. Then, too, the mode of construction has to be considered, and the thickness of the plates used. These the writer mentions in some detail. The character of the water used, too, is of great importance. If it be acid or alkaline, the metal is destroyed. Neutralisation and frequent washing out are then necessary. The writer heard recently of a case where the ingot metal that had been used was stated to be of an unsatisfactory character, and he found the cause to lie, not in the metal at all, but in the improper treatment of the boiler in connection with the last point

above referred to. On some parts of the Chicago, Milwaukee, and St. Paul Railway, the water that has to be used is excessively alkaline. To avoid this, a cement bottom is sometimes put in and a false plate, which becomes rapidly corroded while the boiler itself is not attacked. Some letters relating to this subject by S. P. Busch, P. H. Coradson, and G. Gibbs are also given. The results of their experience is decidedly in favour of the ingot metal, provided the boilers are properly fed and looked after. G. Gibbs observes with regard to fireboxes, that as long as  $\frac{3}{8}$ -inch metal was used in their construction the results were unsatisfactory, but since  $\frac{5}{16}$ -inch metal has been employed these difficulties have not been met with. Soda is generally used to keep the boilers free from scale, and this doubtless adds greatly to the life of the firebox. Of 215 fireboxes removed from the locomotives on the Pennsylvania Railway in the years 1888-94, the maximum number of miles run was 498,439—in the case of a passenger engine—and the smallest 86,830 miles. The average life of a firebox was seven years and two months. One engine had been constantly in use for seventeen years and eight months, whilst the shortest period of use was two years and nine months. Tensile tests of the material used in the construction of such fireboxes are given, and these show tensile strengths of from 56,800 lbs. per square inch to 60,900 lbs., and elongations ranging from 26·5 to 30 per cent. on 8-inch lengths. Kreuzpointner considers the bad results obtained in Prussia to be due to the fact that the plates used are much too thick, and to local galvanic action having set in, and not to any unsatisfactory physical or chemical properties of the metal itself. Plates 0·67 inch thick have been used, but a thickness of even 0·39 inch has been shown in practice to be distinctly too much, and even 0·31 inch seems too high. The pressure used with these thicknesses of plates on the Pennsylvania Railway ranges from 180 to 190 lbs. per square inch. It is a question of the proper transfer of heat to the water without such extreme variations in the temperature of the two sides of the plate itself. Thin plates are evidently more advantageous in this respect than thicker ones.

The ingot metal used should not be too soft, or otherwise it would not be adequately stiff with such thin plates as those recommended. A sample of a material which gave excellent results in practice had the following chemical percentage composition:—

Carbon.	Manganese.	Phosphorus.	Sulphur.	Silicon.
0·155	0·350	0·053	0·077	0·002

It had a tensile strength of 24.8 tons per square inch, a limit of elasticity of 13.2 tons per square inch, and an elongation of 24.5 per cent. The author finds that by polishing and etching the metal a good idea can be formed as to its quality, and such a test applied to the above sample gave a satisfactory result. The test is useful in distinguishing between old and new materials. The sulphur in the above sample is somewhat high from the point of view of the limits adopted by the Pennsylvania Railway Company, but the other constituents exist in satisfactory percentages.

In reply to Kreuzpointner's criticism of the bad results obtained with the use of ingot metal for locomotive fire-boxes in Prussia as compared with the United States, Von Borries\* states, in considering the difference in the results, that the material used in Prussia was somewhat softer, its tensile strength being from 22.9 to 26.0 tons per square inch as compared with the 24.5 to 30.3 tons mentioned by Kreuzpointner. This slight difference may, perhaps, have caused a somewhat more rapid rusting, but, on the whole, can have been of little importance. The plates used were 0.35 inch thick, instead of 0.30 inch. When the author visited the United States in 1891, the plates in general use there were 0.30 inch in thickness. In Prussia the excess pressure in use was 12 atmospheres, and the slight increase in the thickness of the plate used appears therefore accurate. The locomotives in Prussia are allowed to go cold after each period of service, and in this respect the conditions of working are very different from those existing in the United States. Other points of difference are also touched upon. The author anticipates shortly experimenting with an ingot metal firebox made of 0.29-inch plate. A firebox of nickel ingot iron is also in course of construction. This will be of 0.28-inch plate.

**Steel Rails.**—In an editorial criticism in *Stahl und Eisen*† of the paper by A. R. von Dormus, it is pointed out that etching tests have long been in use at many German steelworks, and reference is made to the well-known work of Tetmajer in this direction, and it is further pointed out that the conclusions he has arrived at are in diametrical opposition to those mentioned in this paper, and similar opposite results have been obtained elsewhere. A warning is therefore given not to attach too much weight to the author's generalisations, or to the distinction he draws between the surface steel and the core steel as a

\* *Stahl und Eisen*, vol. xvii. pp. 276-277.

† Vol. xvi. pp. 909-911.

necessary attribute of a rail section. It is also observed that the author appears to have attached too little value to the influence exerted by the mechanical treatment to which the metal had been subjected.

C. L. Allen \* notes the fact that rails containing more carbon than the standard proposed some years ago have been used with success, showing less wear than the softer rails, and not breaking, as was expected. Tram-rails in Syracuse are now being laid 60 feet long and 9 inches high containing—

C.	P.	S.	Mn.	St.
0·53 to 0·63	Not over 0·095	Not over 0·07	0·8 to 1·0	0·10 to 0·12

L. von Tetmajer † publishes the results of an interesting series of tests of steel rails. The basic Bessemer steel rails, in whose manufacture spiegeleisen had been used, which were examined at the Swiss Testing Institute, were found to contain—

Carbon.	Manganese.	Silicon, Phosphorus, Sulphur.
0·20 to 0·46	0·35 to 1·00	Mostly under 0·1

Occasionally the manganese exceeded 1 per cent. The results of tests from the centres of the rail-heads are variable. They frequently break with too little elongation and reduction of area. In actual use in practice these rails gave satisfactory results. The way in which the metal wears is dependent on its structure, blowholes, and inclusions. In tabular form are given the results of etch-tests taken from the upper, central, and lower portions of a number of rail samples. These related to metal having the composition—

No.	Carbon.	Manganese.	Silicon.		Phosphorus.
			Per Cent.	Per Cent.	
1.	0·310	0·957	...	...	0·055
2.	0·320	0·772	...	...	0·090
3.	0·310	1·117	...	...	0·080
4.	0·280	0·936	0·119	0·070	
5.	0·250	0·785	0·103	0·070	
6.	0·250	0·906	0·105	0·060	
7.	0·300	0·875	...	...	0·090
8.	0·290	0·785	...	...	0·075
9.	0·300	0·785	...	...	0·095

The results are stated in each case. Numerous blowholes and liquation products are noted, a more or less pronounced core formation being usual.

\* Paper read before the New York State Street Railway Association, through the *American Manufacturer*, vol. lix. p. 551.

† *Schweizerische Bauzeitung*, vol. xxviii. No. 19.

Rails made with the simultaneous use of ferro-manganese and ferro-silicon usually contained—

Carbon.	Manganese.	Silicon.	Phosphorus, Sulphur.
Under 0·3	Frequently up to 1·0	Usually 0·2 to 0·3	Usually under 0·1

The silicon was very variable.

Some samples proved perfectly homogeneous, and most were almost homogeneous and free from blowholes. In some cases liquation was observed. These products occasionally come together in the rail-head and pass down through the web to the rail-foot. Such rails for equal hardness wear better than others whose running surfaces are spotted from this cause. The joint use of ferro-manganese and ferro-silicon requires great care and careful addition of scrap to keep the temperature down. Too high a temperature may result in ingots with large numbers of blowholes near their surface. Samples made in this way were etched, and the results are noted as before. The chemical analysis showed them to contain—

No.	Carbon.	Manganese.	Silicon.	Phosphorus.
	Per Cent.	Per Cent.	Per Cent.	Per Cent.
1.	0·220	0·967	0·208	0·050
2.	0·250	1·189	0·229	0·060
3.	0·215	0·884	0·182	0·065
4.	0·250	0·762	0·168	0·040
5.	0·190	0·798	0·183	0·060
6.	0·190	0·884	0·222	0·055
7.	0·210	0·701	0·128	0·070
8.	0·210	0·732	0·185	0·070
9.	0·245	0·610	0·237	0·100
10.	0·250	0·701	0·201	0·065

The core formation is not so frequently noted in the results of these tests.

At the Phœnix Works the Darby-Spannagel process is used, and then ferro-silicon. The steel is quiet in the moulds, and usually gives sound castings. Tests of these are also given. The following method of etching is strongly recommended. The well-polished sample is brushed clean with an alcoholic soda or potash solution, washed with ether and alcohol, and then hung in a solution of 100 grammes of sublimed iodine and 200 grammes of potassium iodide in 1 litre of water. After about two minutes the sample is removed, thoroughly brushed under a water-jet, and then re-etched with hydrochloric acid of 50 per cent. strength; and then, if it is to be preserved, washed with ether, dried, and coated with a thin layer of varnish dissolved in toluol.

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In the formation of the edge steel (*Randstahl*), chemical changes appear to play a part; and soft ingot iron appears to more readily form this "edge steel" than steel, and manganese steel to do so more readily than silicon steel. Silicon and carbon appear to hinder this formation, and manganese to assist it. The core steel, surrounded by a blowhole layer, appears darker, more porous, and larger grained than the edge steel. In it are the liquation products and the slag inclusions. The former, on etching with iodine, show round spots or accumulations, whilst the latter appear as more or less jagged inclosures, or filling the pores, due to the casting. Liquation products are readily detected by scratching, as they at once show their metallic structure. Slag inclosures always form small accumulations, and never pass in a pipe-like fashion through the metal. Separate analyses of the edge steel (working face of the rail) and core steel (centre of the rail-head) are given in a large number of instances. The following are a few of these :—

	C.	Mn.	Si.	P.	S.
	Per Cent.				
<b>Acid Bessemer steel rails :—</b>					
Surface . . . . .	0·206	0·800	0·285	0·129	0·047
Core . . . . .	0·202	0·800	0·333	0·126	0·045
Surface . . . . .	0·291	0·279	0·015	0·089	0·015
Core . . . . .	0·332	0·296	0·027	0·118	0·027
Surface . . . . .	0·277	0·597	0·328	0·108	0·065
Core . . . . .	0·273	0·603	0·325	0·106	0·068
<b>Average of a series :—</b>					
Surface . . . . .	0·250	0·510	0·178	0·102	0·038
Core . . . . .	0·262	0·504	0·185	0·109	0·043
<b>Basic Bessemer steel rails :—</b>					
Surface . . . . .	0·296	0·650	0·011	0·067	0·050
Core . . . . .	0·355	0·662	0·011	0·085	0·060
Surface . . . . .	0·367	0·385	0·004	0·086	0·035
Core . . . . .	0·355	0·380	0·001	0·094	0·055
<b>Average of a series :—</b>					
Surface . . . . .	0·317	0·697	0·088	0·099	0·054
Core . . . . .	0·330	0·701	0·098	0·105	0·062

Similar results relating to other kinds of rails are also given. The conditions of the tests to which the rails should be submitted before acceptance are then discussed, both physical and chemical tests being necessary.

In the period October 1893–1894, the *Verein Deutscher Eisenbahnverwaltungen* submitted to mechanical tests a large number of samples of railway material. Details as to the results are now

published.\* With rails, 4270 tests of new material were made. Of these, 3665 were falling-weight tests and 605 transverse tests. The latter were all satisfactory, and they comprise 75 Bessemer rails, 211 basic Bessemer rails, 318 basic open-hearth rails, and 1 acid open-hearth rail. These tests were made by resting the rail upon two supporting points at a distance of 39 inches from each other, then allowing a steady pressure of from 13·4 to 27·3 tons to act on the rail for a period of five minutes. As a rule, no lasting deflection, or at most only a very slight one, should then result. Then the pressure was increased, pressures of from 27 to 49·5 tons being employed. Under this the rails should neither fracture nor show cracks. Some works stipulate for a certain angle to which the rail should be capable of being bent without showing cracks.

The following transverse tests are also described. Again the rail rests on supports 1 metre apart, and is subjected to blows from weights of 0·3, 0·4, or 0·5 ton, and in Austria up to 0·6 or 1·0 ton, while the heights of the tests at the different places from which returns were received varies from 0·5 to 10 metres. A moment of 3000 metre-kilogrammes was stipulated for in most instances. Under this the rails must not be damaged. At thirty-three establishments 3502 tensile tests were made. Satisfactory results were in most instances obtained. Tests of axles, tyres, and numerous other kinds of railway material are also given. Fourteen firms made tests of boiler-plate. In 559 cases weld iron sheets were examined. These were all satisfactory. So, too, were the 63 acid open-hearth plates tested, while of 830 basic open-hearth boiler-plates examined only 0·4 per cent. proved unsatisfactory.

**Tests of a Railway Axle.**—W. F. M. Goss † gives the results of a test of a wrought iron railway axle supported on its bearings and the load applied to the wheels. The deflections of various points up to a load of 85,000 lbs. are given. On a test specimen the elastic limit was 30,000 lbs., ultimate strength 51,070 lbs., elongation in 8 inches, 27·3 per cent.

**Railway Wheels.**—R. C. P. Sanderson ‡ gives the costs of cast iron and steel tired wheels for railway vehicles, and shows that chilled wheels are good enough for ordinary service.

\* *Stahl und Eisen*, vol. xvi. pp. 999-1002.

† "Digest of Physical Tests," vol. ii. pp. 85-91.

‡ Southern and South-Western Railway Club, through the *Iron Age*, vol. lviii. p. 817.

At the Altoona shops of the Pennsylvania Railroad,\* a method of testing wheels which has been in vogue for some time has provoked a considerable amount of discussion. It consists in placing the wheel in a sand mould so as to leave a space two inches wide round the tread, and then pouring molten iron into this space. Most of the wheels tested in this way break or crack in 25 seconds to 1½ minute after the metal is poured. It is contended by many that this test serves no practical purpose, and that it is extremely unfair.

**Iron Cylinders for Holding Gas.**—A further contribution to the study of this question is published by A. Martens.† He gives a list of a series of papers which have appeared on this subject, and with which he deals. He enumerates as follows the causes which may bring about the explosion of a bottle:—(1) The setting fire to an explosive gas mixture; (2) overcharging the bottle with permanent gases, and especially with liquefied gases; (3) faults in the construction and preparation of the bottles; and (4) external damage. These he deals with in detail, pointing out numerous sources of danger.

**Trials of Armour-Plate.**—On September 15 and 16, 1896, armour-plate trials took place under Austrian official supervision at Witkowitz. These are now described.‡ It was desired to ascertain what progress had been made by the Witkowitz Works in the manufacture of armour-plate since the great comparative trials at Pola in 1893. A Harveyed plate of special steel was submitted to test, and also a homogeneous steel plate without face-hardening. It was desired from the result of this trial to select the armour-plate to be used in the construction of new ironclads. The results of the tests showed that both plates were of far better quality than was the standard plate of the Witkowitz works, which at the Pola trials was found better than all the other plates, both German and English, that competed with it. Other comparisons in favour of the new Witkowitz results are also stated.

It is reported § that last November at Ochta an 8-inch gun drove a shot through a Krupp 10-inch steel plate with a hardened face. The striking velocity is given as 2850 foot-seconds, and it is stated that the projectile emerged at the back with a velocity of 700 foot-seconds.

\* *Iron Age*, vol. lviii. p. 879.

† *Stahl und Eisen*, vol. xvi. pp. 897-906, with nine illustrations.

‡ *Mittheilungen aus dem Gebiete des Seewesens*, Part 2, 1897; *Stahl und Eisen*, vol. xvii. pp. 261-263, with three illustrations.

§ *Engineer*, vol. lxxxiii. p. 213.

Details as to the weight of the shot are uncertain, but the result shows that the plate was good.

A test was made in February of a 4-inch armour-plate at Indian Head with a 5-inch gun. Two shots were fired with striking velocities of 1530 and 1980 foot-seconds. The second shot only produced a slight indentation.\*

**Nickel Steel Armour.**—H. W. Raymond † traces the history of nickel steel in metallurgy, mechanics, and armour. Although previous experiments had been made on this alloy, no general attention was paid to it until a paper was read by J. Riley before the Iron and Steel Institute in 1889. The immediate result was that the United States investigated the application to armour, with the result that a nickel steel plate far outdistanced all steel and compound armour, and now nickel steel is almost exclusively employed in that country. Other applications are briefly mentioned.

**Gauges for Plates.**—At a meeting of the American Steel Manufacturers' Association, held October 1896, the question of gauges for plates was discussed, and it was resolved to adhere to the gauge adopted in June 1894 by the American Master Mechanics' Association, and since then by all the principal railways in the United States, Canada, and Mexico. This gauge gives the thickness of plates in thousandths of an inch from 0·002 up to 0·250 inch. The United States standard gauge, as used by the customs and based on the weight of iron, was condemned.‡

The report of A. L. Colby to the first named of the above associations is summarised by R. W. Raymond. §

\* *Iron Age*, vol. lix. No. 7, p. 6.

† *Engineering Magazine*, vol. xii. pp. 838-845.

‡ *Iron Age*, vol. lviii. pp. 819-821.

§ *Transactions of the American Institute of Mining Engineers*, 1897, Chicago meeting (advance proof).

## CHEMICAL PROPERTIES.

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**Iron Carbide in Steel.**—F. Mylius,\* F. Förster, and G. Schoene state that the separation of carbon by means of an electric current from steel which had been annealed yielded residues containing from 7 to 9 per cent. of carbon and about 90 per cent. of iron. While, however, the tool steel, containing 1·30 per cent. of carbon, was completely soluble even in hot hydrochloric acid, the residue obtained by the electrolytic method always contained an insoluble carbonaceous residue. Similar observations were made when the steel was dissolved in chromic-sulphuric acid, due apparently to a partial decomposition of the carbides present. Only dilute acids were, therefore, used in the subsequent experiments for the separation of the carbon. But even in this case the residues cannot *a priori* be accepted as iron carbides. For instance, steel low in carbon is readily attacked by normal sulphuric acid, but at the end of a week the evolution of hydrogen entirely ceases, and there remains a dark spongy porous residue, which, under the microscope, shows particles with a metallic lustre. Such a residue, when dried and analysed, was found to contain a considerable quantity of iron and 3·5 per cent. of carbon. It dissolved in boiling hydrochloric acid with an evolution of gas, leaving a residue containing 7 per cent. of carbon, and in addition, silica, iron, manganese, copper, and phosphorus, whilst arsenious acid was also present. From a tool steel 16·8 per cent. of residue was obtained with a sulphuric acid solvent, and this contained—

C.	Fe.	Mn.	Si.	Cu.	H + O + Loss.	Total.
6·5	89·6	0·6	0·3	0·2	2·9	100·0

To obtain residues completely soluble in hydrochloric acid, both the solution of the steel and the washing and drying of the residue must be effected out of contact with the air. For subsequent experiments a steel was used containing—

C.	Mn.	Si.	P.	S.	Cu.
1·30	0·30	0·21	0·11	0·05	trace

\* *Zeitschrift für anorganische Chemie*, vol. xiii. p. 38.

This was dissolved in a dilute hydrochloric acid containing about 7 per cent. HCl. The residue, when dissolved in 15 per cent. HCl, gave scarcely 0·15 per cent. of its weight as an insoluble residue, and this was mainly silica. Its loss of weight on drying was at most 0·4 per cent. The analysis of various carbide residues obtained in this way gave 6·50, 6·56, and 6·44 per cent. of carbon. One such residue contained—

C.	Fe.	Mn.	Cu.	Si	S+P+As+Ni. traces
6·50	91·96	1·10	0·23	0·02	

The residue obtained in this way retains the form and size of the original metal, and consists of a network of entangled lustrous needles and plates. Dried at 100°, it is pyrophoric. On heating in a current of hydrogen it loses weight, but this loss is so slow—scarcely 0·5 per cent. in an hour—that the short heating to redness required for analysis is of no consequence. The carbide after having been heated to redness is usually not pyrophoric. Dry carbide is not affected by contact with the air at ordinary temperatures, but at higher temperatures it readily takes fire. Moist carbide is rapidly converted into a brown powder in contact with the air, which leaves a dark brown residue containing water when the iron oxide produced is dissolved away. This substance is also produced in the Eggertz carbon test. Water does not act on the carbide at ordinary temperatures, but it does so readily at 100°. When 1 gramme of the carbide and 5 cubic centimetres of the water were heated together in a closed tube for three hours to a temperature of 145°, half a cubic centimetre of combustible gas was produced. Other results of different methods of treatment are also given. In conclusion the authors observe: (1) That steel previously raised to redness (? annealed) consists of a coarse mixture of crystallised iron and crystallised iron carbide; (2) that the iron carbide is a chemical compound of the formula  $\text{Fe}_3\text{C}$ , resembling  $\text{Mn}_3\text{C}$ , but it differs from this by greater indifference to the action of solvents; (3) that iron carbide—the “carbide carbon” in steel—is insoluble in dilute acids; (4) that it can be dissociated, being converted by heat into carbon and iron poor in carbon, from which latter on slow cooling carbide again separates out; and (5) that at a bright red heat iron carbide can enter into chemical reaction with iron.

H. von Jüptner,\* referring to recent experiments, points out that as the carbide is so readily attacked, even by dilute acids, it is evident that previous determinations of carbide carbon may have given results

\* *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xlv. p. 123.

which were too low, and that consequently the determination being by difference, the percentage of hardening carbon shown was similarly too high. The authors first referred to state that hardened steel contains no carbide, or at least considerably less carbide than does annealed steel.

In the Report of the *Physikalisch-Technische Reichsanstalt*\* it is stated that during the year the question of the carbides contained in steel has been carefully studied. Various kinds of iron were examined, pure electrolytic iron and pure carbon being heated together in an atmosphere of nitrogen. Fireclay retorts were employed in this operation. The investigations have thus far shown that, at its melting temperature, the maximum percentage of carbon that can be taken up by pure iron is 5. From the non-saturated solution of carbon in iron (cast steel) there liquates on cooling an iron carbide of definite composition, which is also present in weld steel. It is a true compound, its composition being independent of the degree of concentration of the carbon in the iron. It forms iron-grey magnetic scales, which are not acted upon by water or dilute acids in the cold, but which are dissolved, with decomposition, in hot hydrochloric acid, and are attacked by oxidising agents. From hardened steel this carbide cannot be obtained, and it may therefore be assumed that when the steel is heated to bright redness, the carbide enters again into reaction with the adjacent iron. Further investigations of the hardening process are to be made.

In a paper on the modifications of carbon in iron, Baron H. von Jüptner † states that, accepting Lebedur's original classification, it is now generally agreed that there are four forms in which carbon occurs in iron: (1) *Graphite*, crystallised carbon that has separated out, and which is not acted on even by boiling acids. (2) *Graphitic temper carbon*, carbon which has separated out in an amorphous form, which behaves towards acid in the same way that graphite does, is black without lustre, and completely amorphous, burns more readily than graphite, and which can by ignition under oxidising conditions, and even by heating in a current of hydrogen, be entirely removed from the iron. (3) *Hardening carbon*, occurring in all varieties of iron, at least in traces, evenly divided throughout the main mass of the metal and imparting the degree of hardness it possesses; on

\* *Zeitschrift für Instrumentenkunde*, 1896, Parts VII. and VIII.; *Stahl und Eisen*, vol. xvi. p. 841.

† *Kohlenstoffformen im Eisen*, Stuttgart, 1896. A copy of this work has been presented by the author to the Institute Library.

dissolving the iron in dilute hydrochloric or sulphuric acid, it escapes as a strong-smelling hydrocarbon, and on dissolving the metal in hot nitric acid of 1·2 specific gravity, it first forms a deep black residue which dissolves rapidly on shaking, and in a few minutes, if not shaken, without any visible evolution of gas, and escapes gradually as gas when the solution is heated to 100°, the solution, at first of a dark colour, due to its carbon contents, gradually growing lighter in colour as the gas escapes. (4) Ordinary carbide carbon is, with from thirteen to fifteen times its weight of iron, distributed in a network throughout the main mass of the metal, the formula  $\text{Fe}_3\text{C}$  agreeing with the composition of the iron carbon compound present. On heating in strong acids, this compound escapes in the form of hydrocarbon. If the metal is dissolved in strongly-diluted hydrochloric or sulphuric acid at the ordinary temperature, the above so-called carbide remains undissolved as a grey or brownish coloured mass, which consists of granules having a silvery lustre, and take fire readily at a comparatively low temperature when dried. On dissolving the iron in cold dilute nitric acid of 1·2 specific gravity, the "carbide" remains undissolved as a voluminous brown substance, which on heating gradually dissolves without any evolution of gas, and imparts a brown colour to the solution, this coloration only slightly changing when the solution is heated.

This classification leaves out of consideration other possibly existing carbon forms. With regard to the formation of these and their changes one into the other, the following view is taken:—The molten iron contains the carbon evenly distributed throughout, probably dissolved like silicon, or, as some suppose, in the form of hardening carbon. If the percentage of the carbon is high enough, a portion of it separates as graphite when the metal cools. This separation of graphite goes on after the molten metal has become solid, and indeed reaches its maximum at a temperature lower than the solidifying point, gradually falling again subsequently as the temperature continues to fall. At still lower temperatures, according to Howe's assumption, amorphous carbon (temper carbon) separates out in the place of graphite, and graphite may even be converted into such temper carbon, though this has not yet been verified. That portion of the total carbon retained in iron in a form other than that of graphite is present, if the temperatures be high enough, in the form of hardening carbon. As the temperature slowly falls, then between certain temperature limits this hardening carbon changes

into carbide carbon. Sudden cooling causes the carbon to remain in the same condition as that in which it existed at the moment when the metal was cooled. Inversely, on slowly heating iron containing carbon, the carbide carbon passes into the hardening carbon form. As the temperature goes on rising, so this form of carbon again undergoes change, and at a red heat it begins to be converted into temper carbon, and this conversion is the more complete the longer is the metal allowed to remain at the temperature in question, a temperature lying between that at which carbide forms and that at which graphite separates out.

S. S. Knight \* comments on the slow progress in the knowledge of the chemical and scientific components of the iron industry. The author also considers the subject of carbon in its relation to iron, and gives the results of experiments.

**Ferro-Manganese.**—An average analysis of ferro-manganese is given as follows :—

Manganese.	Carbon.	Silicon.	Iron.	Phosphorus.	Sulphur.	Total.
80·00	5·00	0·50	14·25	0·20	0·05	100·00

Spiegeleisen ranges from 12 to 20 per cent. of manganese, with 60 to 75 per cent. of iron, 2 to 4 per cent. of carbon, and not over 0·05 per cent. of sulphur.

**Liquation Phenomena in Ingot Metal.**—A. Ruhfus † observes that even the falling down of an ingot, the centre of which is still fluid, may lead to hollow or double sheets or other irregularities in the subsequent manipulation of the metal. The last cast ingot of a charge frequently suffers in this way if slag has found its way into the centre of the ingot. Too large an addition of ferro-silicon or aluminium may lead to such a result. In the hollow pieces slag may be found in the form of a fine grey-green powder. On collecting this, and after separating any admixed metallic iron by means of a magnet, analysis shows this slag to have a peculiar composition. This will be seen from the following analyses, which are of such slag found in the hollows of metal from three separate charges made at different times :—

\* *Foundry*, December 1896.

† *American Manufacturer*, vol. lx. p. 299.

‡ *Stahl und Eisen*, vol. xvii. pp. 41–44, with six illustrations.

	FeO.	MnO.	SiO <sub>2</sub> .	CaO.	S.	P <sub>2</sub> O <sub>5</sub> .
	Per Cent. 24·74	Per Cent. 63·03	Per Cent. 9·16	Per Cent. 0·64	Per Cent. 0·61	Per Cent. 0·227
II. . . .	27·01	59·05	10·18	0·84	0·76	0·316
III. . . .	23·12	71·02	5·01	0·21	...	0·090

In most cases the occurrence of such slag, in the author's experience, points to faulty treatment. In open-hearth ingot metal it was of more frequent occurrence when a large percentage of pig iron was used, and the fusion process shortened by the use of ore or roll scale. In the case of basic metal a badly-selected pig iron, with too much phosphorus and too little manganese, led to this result. Such charges work very hot, and are frequently too completely decarburised ; and after the addition of the ferro-manganese are rapidly cast, with a view to effect a saving in this material. The oxidised iron, which naturally exists in considerable quantities in such metal, has an inadequate time allowed for its reduction, and this then continues in part in the ladle or in the ingot mould. The oxygen of the iron combines in part with the manganese, and during the escape of the gases from the ingots the specifically lighter oxygen compounds seek to reach the upper portions of the ingots as well also as any slag that may be present. If, however, the ingot solidifies before this separation has been completely effected, they remain mingled with the metal, and if present in large enough quantity, separate out from the metallic iron, and are then found in the sheets as slag of the composition given above. A slag removed from an ingot showed a similar composition :—

FeO.	MnO.	SiO <sub>2</sub> .	CaO.	S.	P <sub>2</sub> O <sub>5</sub> .
23·82	60·45	7·71	5·92	0·59	0·26

Charges cast from above into large moulds were found to give faulty sheets, while if the metal from the same cast is cast in smaller rising moulds the sheets are perfectly satisfactory. Liquation is evidently the cause of this irregular behaviour. For reasons which the author states, the most liquation takes place in the upper third of the ingot, and in the centre of this portion. This liquation is greater when the metal cast is hotter and when the quantity of gas which it contains is larger. The hotter and more thin-fluid is the metal, the more free from oxide is the outer portion of the ingot, and the richer in oxides is the central portion. Inversely, in cold casts the central portions of

the ingots show on etching a dense structure, while the separated oxidised portions occur as a kind of ring between the dense centre and the face. Face blowholes which are not due to faulty casting only occur in cold-blown or thick-fluid charges. Were it possible to keep the fluid steel for only an hour in the ladle, or in any closed vessel, without a diminution in temperature resulting, a steel would be obtained which would possess the properties of crucible steel, which is nothing more than perfectly liquated steel—steel, that is, without oxygen compounds.

In connection with the gas contents of fluid ingot metal, the author refers to the marked action of aluminium in certain cases. The following are a number of analyses made of gases collected from the metal on casting :—

Percentage Composition.					The Steel in the Mould.
CO <sub>2</sub> .	O.	CO.	H.	Total.	
7·4	1·00	52·8	27·46	88·66	Sank
7·2	0·01	60·1	21·0	88·31	Steady
8·2	1·10	63·8	18·0	91·10	Sank
2·1	0·30	69·4	16·8	88·60	Sank
3·9	1·0	70·0	19·1	94·00	Sank
8·3	0·2	73·3	13·3	95·10	Steady
3·0	0·7	77·0	6·0	86·70	Steady
5·2	0·5	81·7	5·3	92·70	Rose
4·0	0·0	82·0	4·8	90·80	Steady
2·7	0·3	86·2	4·0	92·20	Rose

When the metal sank in the ingot the aluminium exerted a marked action, but this was not the case with rising metal. The analyses showed that sinking metal was marked by a high percentage of hydrogen in the gas collected. The author discusses the origin of the different gases, the presence of which was observed, and the action of additions such as the aluminium mentioned above. The following are the results of mechanical tests of samples of the same metal with and without the addition of aluminium :—

	Without Aluminium.			With Aluminium.		
	Tensile Strength.	Elongation.	Reduction of Area.	Tensile Strength.	Elongation.	Reduction of Area.
	Tons per Square Inch.	Per Cent.	Per Cent.	Tons per Square Inch.	Per Cent.	Per Cent.
I. . .	26·8	27·0	51·0	25·5	22·0	36·0
II. . .	26·7	26·5	55·7	26·3	23·0	33·6
III. . .	26·2	23·0	57·7	25·6	21·5	57·7
IV. . .	26·3	28·0	60·0	26·7	24·0	61·0

The etched samples of the metal made without the addition of aluminium showed that there had been liquation, whilst the metal made with the aluminium addition was perfectly homogeneous. An addition of ferro-silicon causes the tensile strength of the steel to increase by about 0·6 ton per square inch on account of its carbon contents. It is remarkable that in the case of harder metal the action of such an added material is always favourable, due probably in the first place to the higher percentages of carbon and manganese which such metal contains.

**Some Iron Alloys.**—M. Martino\* observes that for drills and cutting tools new alloys are being produced. Tools made of these are just as hard as those made from ordinary steel hardened, and they possess the advantage that they do not lose their hardness by becoming heated during use. The material mentioned can be used in all cases in which ordinary steel is now employed. While possessing a constant general character, the relative percentage of the various constituents may be changed according to the kind of use to which the tool is subsequently to be put. The following is such an alloy suitable for drills :—

	Per Cent.
Cast iron . . . . .	17·25
Ferro-manganese . . . . .	3·00
Chromium . . . . .	1·50
Tungsten . . . . .	5·25
Aluminium . . . . .	1·25
Nickel . . . . .	0·50
Copper . . . . .	0·75
Bar iron . . . . .	<u>70·50</u>
Total . . . . .	100·00

Another alloy suitable for needles, cutting tools, &c., consists of :—

	Per Cent.
Cast iron . . . . .	17·25
Ferro-manganese . . . . .	4·50
Chromium . . . . .	2·00
Tungsten . . . . .	7·50
Aluminium . . . . .	2·00
Nickel . . . . .	0·75
Copper . . . . .	1·00
Swedish bar iron . . . . .	<u>65·00</u>
Total . . . . .	100·00

The method of producing such alloys is described. A crucible is used.

\* *La Metallurgie*, through *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xlv. pp. 38-39.

**Alloys of Iron with Molybdenum.**—Experiments made at the Le Creusot Works have shown that the addition of 0·2 to 0·3 per cent. of chromium to steel containing 0·2 to 0·3 per cent. of molybdenum, imparts to this steel, after hardening, a higher resistance from an armour-plate point of view without making it more brittle. The metal is generally of excellent quality, and it can be produced either in the crucible or in the converter, the chromium being added as ferro-chrome and the molybdenum in the metallic form, or as an alloy.\*

Hitherto the comparative rarity and the costliness of this element has prevented any use being made of it in the manufacture of iron. Guichard,† however, describes a method by which the metal can be reduced from its sulphide. This sulphide, when heated in a carbon tube for about five minutes by a current of from 900 to 950 amperes and 50 or 55 volts, loses all its sulphur. The metal remaining contains, in addition to any iron that may have existed in the ore, only about some 7 per cent. of carbon. Moissan has shown another modification by which the metal can be obtained in an electric furnace free from carbon. Pure molybdenum has the specific gravity 9·01. Like iron, it may be hammered, filed, polished, and welded. It does not scratch either glass or quartz. It is not attacked either by the air or moisture. On heating in air it colours on the surface, and at about 600° C. it begins to oxidise to molybdic acid, which volatilises. Molybdenum readily dissolves carbon, and the resulting carbide is more readily fusible than the metal. This carbide when fused dissolves a still further quantity of carbon, but on cooling this separates out again in the form of graphite. When heated to about 1500° for a long time in the presence of carbon, it takes up a little carbon and will then scratch glass. If the metal so obtained is subsequently heated to 300° and then plunged into cold water, it becomes so hard that it will scratch glass. Inversely, molybdenum containing carbon when cemented in molybdic acid loses the carbon and becomes pure.

It will be seen from this summary of the properties of molybdenum that that element in many respects resembles iron, and it is thought that it may prove useful as a deoxidising agent for iron, as, when added to the molten metal, any molybdic acid that might be produced would be volatilised.

\* *La Métallurgie*, March 4, 1896, through the *Oesterreichische Zeitschrift für Berg- und Hüttewesen*, vol. xliv. p. 590.

† *Comptes Rendus*, vol. cxxii. p. 1270; *Zeitschrift für Elektrochemie*, ii. p. 265, iii. 92; *Stahl und Eisen*, vol. xvi. pp. 693-694.

**Action of Water upon Iron.**—According to F. W. Durfee,\* it was found that the cast iron girders used for structural purposes within the Hubb coal-mine had undergone such radical changes that, while retaining their original size and shape, they could easily be broken, and were no longer strong and fairly tough like cast iron.

**Corrosion of Steel.**—A. H. Sabin † gives the results of some experiments on the protection of steel and aluminium exposed to sea-water. Plates of boiler steel  $\frac{3}{16}$  inch in thickness were coated with various varnishes and preparations, and exposed to sea-water for six months and their behaviour noted. In the discussion a number of similar tests were mentioned, amongst which are some of iron and steel pipe in water, clay, and sand.

**Influence of Salt Solutions upon Iron.**—R. Petit ‡ has examined into the question of the action exerted by various salt solutions upon iron. The solutions experimented with were the following :—

	Strength.
Calcium chloride . . . . .	0·105 gramme per litre.
Common salt . . . . .	0·110     ,,     ,,
Potassium sulphate . . . . .	0·091     ,,     ,,
Calcium nitrate . . . . .	0·092     ,,     ,,

The same quantities of iron filings were placed in contact with each of these solutions for eleven days, at a temperature of 12° C. Salt solutions containing dissolved carbonic anhydride and solutions free from this gas were employed. The latter at the end of the test contained only traces of dissolved iron. For every 100 parts of iron used in the test, at the completion there had been formed :—

Solution.	Without CO <sub>2</sub> , Iron Oxide.	With CO <sub>2</sub> .	
		Iron Dissolved.	Iron Oxide.
	Per Cent.	Per Cent.	Per Cent.
Distilled water . . . . .	3·8	9·7	3·2
Common salt . . . . .	7·7	9·7	7·8
Potassium sulphate . . . . .	7·5	14·8	7·7
Calcium nitrate . . . . .	4·2	3·7	4·4
Calcium chloride . . . . .	6·2	6·3	6·4

\* *Journal of the American Chemical Society*, December 1896.

† *Transactions of the American Society of Civil Engineers*, vol. xxxvi. pp. 483-508.

‡ *Comptes Rendus de l'Académie des Sciences*, vol. cxxii. p. 1278.

Each salt, that is, has its own definite degree of action upon the iron, and this is not relatively affected by the presence of carbonic anhydride. The solution of the iron is almost solely due to the carbonic anhydride. In the presence of a small quantity of air, the iron dissolved did not increase, but there was a rapid increase in the quantity of iron oxide produced.

**Action of Oils on Iron.**—In a paper on lubricating oils read before the South Staffordshire Institute of Iron and Steelworks Managers,\* A. E. Tucker states that by acting on iron for twenty-six hours he obtained the following amounts of metal dissolved in 500 cubic centimetres of oil :—

Oil used :—

Sperm . . . . .	0·0370
Lard . . . . .	0·0120
Olive . . . . .	0·0314
Castor . . . . .	0·0034
Valvoline . . . . .	nil
Cylinder oil, specific gravity, 0·921 . . . . .	trace
Lubricating oil, specific gravity, 0·915 . . . . .	trace

**Paint.**—M. P. Wood † vigorously attacks the use of iron oxide paints for coating iron and steel, and also points out the imperative necessity for more carefully applying the paint.

**Oxides in Iron and Steel.**—W. Galbraith ‡ discusses the presence and influence of oxides in iron and steel. In very soft basic open-hearth steel the author has already pointed out § that so-called wild and cold heats are not so much due to lack of heat as to the extraordinary infusibility of the metal, and that it is always concomitant with an excess of oxide of iron in the slag. This behaviour may be explained by the presence of some oxide in the metal, possibly Fe<sub>2</sub>O<sub>3</sub>, and arguments are advanced to prove the possibility of this assumption. Similar occurrences may take place in the basic and acid Bessemer processes. In the latter, after blowing well down, the metal is allowed to stand in the converter, and possibly then the slag may take up more silica from the lining and become less oxidising. Methods

\* January 30, 1897.

† Paper read before the American Society of Mechanical Engineers, through the *Iron Trade Review*, vol. xxix. No. 50, p. 13.

‡ Paper read before the Sheffield Metallurgical Society. A copy of this paper has been presented by the author to the Library of the Iron and Steel Institute.

§ *Journal of the Iron and Steel Institute*, 1890, No. I, p. 134.

have been proposed by the author and others for bringing the metal into contact with siliceous slag for removing oxides. The use of aluminium is then referred to in connection with the "killing" or quieting of crucible steel, and for other purposes. In casting cinder iron on the pig-beds a scum often forms containing—

Silica.	Oxide of Manganese.	Ferrous Oxide.	Alumina.	Lime.	Total.
35·60	50·60	10·30	2·20	1·06	99·76

and this may be accounted for by the action of manganese and silicon on oxide of iron. Some methods for determining the amount of oxygen in iron have been proposed, but are not altogether satisfactory. Both Colonel Dyer and G. J. Snelus have thought that low carbon iron will not work because it contains oxides. In the discussion the effect of aluminium was dealt with amongst other points.

## CHEMICAL ANALYSIS.

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### I.—ANALYSIS OF IRON AND STEEL.

**Some Present Possibilities in the Analysis of Iron and Steel.**—C. B. Dudley,\* in his presidential address at the meeting of the American Chemical Society, gives a survey of some of the analytical methods in use in the iron and steel industry. Only five of the constituents affecting the quality are here considered, namely, carbon, phosphorus, silicon, sulphur, and manganese.

**Determination of Carbon.**—The various combustion methods for the determination of carbon in iron and steel are discussed at some length by W. Galbraith,† who also makes some comments on the Eggertz method. In the latter, errors are due to the non-permanency of the colour, to the fact that the colour depends on the strength, temperature, and time of action of the acid, and perhaps also on the fineness of the drillings, also on the previous treatment of the steel and on the effect of disturbing elements. The personal equation may be lessened to some extent by Lovibond's tintometer. Turning then to the combustion methods, the author shortly summarises those that have been proposed, dealing with the various disturbing factors, and then gives the following, designed to reduce the sources of error as far as possible:—Treat the iron or steel with sufficient chloride of copper solution or ammonio-chloride of copper; with hard pig iron or chro-

\* *Science*, February 12, 1897.

† *Journal of the West of Scotland Iron and Steel Institute*, vol. iv. pp. 71-80.

mium iron, it will be better to use sulphate of copper. After decomposition is complete, add sufficient hydrochloric acid and filter. The filter is made by spreading loose flakes of ignited asbestos over glass beads or broken glass in a tube with a sharp or square neck. Wash well with hot water, transfer by turning upside down in a 6-ounce flask fitted with an indiarubber stopper, having attached a funnel tube and two tubes at right angles. One of these latter, passing to the bottom of the flask, is attached to a chloride of calcium tube with soda lime, or bulbs containing potash. For this purpose Arnold's bulbs are very useful. The other tube is connected to the dehydrating train, which may consist of a 6-inch stoppered U-tube surrounded with water in a beaker, then two Arnold's bulbs with sulphuric acid and another stoppered U-tube with calcium chloride. Then there is a short combustion furnace with a glass or porcelain tube, containing oxide of copper; next another sulphuric acid bulb, followed by one of Geissler's potash bulbs with small chloride of calcium, and a similar guard containing soda lime. The tubes are coupled up and the oxide of copper heated, and there is poured in through the funnel tube about 30 cubic centimetres of equal volumes of sulphuric acid and water, and also sufficient chromic acid. The flask is now heated gently to boiling, the guard being meanwhile connected to an aspirator. After heating sufficiently, the potash bulb attached to the tube is brought into requisition by taking off the plug or stopper, and air or oxygen is drawn through at a convenient speed, the flask and oxide of copper being kept hot. After perhaps two litres have been drawn through, the operation is stopped, and the potash bulbs, &c., weighed.

For the rapid estimation of the total carbon, J. G. Heid \* dissolves a weighed portion of the sample in copper ammonium chloride, filters through an asbestos filter, washes successively with warm water, alcohol, and ether, and then places the filter in a Rose crucible, and dries it at 120° C. After weighing, the crucible is covered with a triangular lid and heated over a Bunsen burner, whilst a steady stream of oxygen is passed through it. In three to five minutes the carbon is burnt off, and the loss of weight, showing the total carbon, is determined. For determining graphite, the same process is followed, except that dilute hydrochloric acid is used as the solvent.

B. S. Summers † gives an illustrated description of apparatus by which the carbon may be determined with reasonable speed and accuracy.

\* *Engineering and Mining Journal*, vol. lxiii. p. 64.

† *Journal of the American Chemical Society*, December 1897.

**Determination of Phosphorus.**—O. Herting \* observes that the volumetric determination of phosphorus—the so-called Emerton method—is not generally employed in Germany, whilst it is so in the United Kingdom and the United States. The titration of the phosphorus, or rather of the molybdic acid in the molybdate precipitate, with permanganate is accurate enough. The author has made numerous comparative determinations between this volumetric method and the gravimetric method, both as the magnesia precipitate and by weighing the molybdate precipitate, and he considers it more accurate at least than the method by weighing the molybdate precipitate. He adopts the following slightly modified method. In the case of pig iron, 1 gramme is dissolved in 50 cubic centimetres of nitric acid of the specific gravity 1·135, the solution heated to boiling, 20 cubic centimetres of a permanganate solution added (8 : 1), boiled for two minutes, and then from a pipette a saturated solution of potassium or ammonium oxalate added drop by drop to bring into solution again the brown manganese precipitate. The whole is then boiled for another two minutes, 5 cubic centimetres of nitric acid of the specific gravity 1·42 added, stirred, allowed to settle, filtered, and the residue washed twice. When the filtrate has cooled down to from 65° to 50°, it is transferred to a beaker which contains from 80 to 100 cubic centimetres of an ammonium molybdate solution heated to 50° C., stirred for a minute, and then placed in some spot having a temperature not exceeding 60° C. In ten or fifteen minutes, the precipitate can be collected on a filter, washed together on the filter with dilute molybdate solution, and then washed with an acid solution of ammonium sulphate until the iron has been washed out. This can be determined by the use of potassium sulphocyanide. The yellow precipitate is then treated on the filter with dilute ammonia, and subsequently washed twice with warm water. The solution is filtered into a small Erlenmeyer flask containing about 10 grammes of zinc, an excess of dilute sulphuric acid added, covered with a funnel, and then placed for eight minutes on a hot plate. In the meantime a rapid filtering filter is prepared, large enough to take the whole solution at once, which is then rapidly filtered, washed once and titrated immediately with a standard solution of permanganate, until the solution, from being brown, green, or port-wine colour, becomes colourless, and the permanganate produces a constant coloration. The value of 1 cubic centimetre of the permanganate solution calculated for iron, multi-

\* *Chemiker Zeitung*, vol. xxi. pp. 188-189.

plied by 0·0164, gives the percentage of phosphorus. The time required for the whole determination is sixty-five minutes. For steel the method is much the same, but graphite and silica need not be filtered off, and forty-five minutes is enough for the analysis. The best nitric acid to use in dissolving iron and steel is one of the specific gravity 1·135. The factor 0·01628 given in English pocket-books and textbooks is inaccurate. It should, as stated, be 0·0164.

The author also discusses other methods. That of Carnot he thinks unlikely to be adopted in practical work, and the author got much too low results by its use. In Mauermann's method the molybdate precipitate is dissolved in dilute ammonia, and the excess of ammonia titrated back by a standard solution of sulphuric acid, corallin being used as an indicator. If this method gave accurate results it would be better than any other, as it is the most rapid. The author was not quite satisfied with the results he obtained, but he intends to continue his investigation of the method. R. Namias, he adds, has proposed a colorimetric method which consists in dissolving the molybdate precipitate in a warm solution of sodium trisulphate, a blue colour resulting, on an estimation of the intensity of the colour of which—like an Eggertz carbon test—the determination depends. After a little practice the intensity of this coloration can be readily estimated. It is, however, a slower and less accurate method than titration.

In order to ensure the complete precipitation of the phosphorus, G. Auchy \* recommends the following process:—Two grammes of steel is dissolved in 100 cubic centimetres of nitric acid of specific gravity 1·13; the solution is partially neutralised by adding 15 cubic centimetres of strong ammonia previously diluted with 50 cubic centimetres of water, and after heating to 85° the phosphoric acid is precipitated by adding 60 cubic centimetres of Blair and Whiffield's molybdate solution. If it is thought desirable to precipitate from a very acid solution, from 15 to 20 grammes of ammonium nitrate should be first added, and the liquid should be somewhat diluted. The author adds a caution as to the occasional presence of phosphoric acid in the reagents used.

**Determination of Sulphur.**—W. Schulte † observes that the difficulties connected with the determination of sulphur in iron by the use of a solution of bromine in hydrochloric acid have led him to devise the following method:—The iron sample is dissolved in fairly

\* *Journal of the Chemical Society*, vol. lxxii. pp. 72-73.

† *Stahl und Eisen*, vol. xvi. pp. 865-869, with one illustration.

dilute hydrochloric acid, and the gases evolved are passed through a solution of cadmium acetate acidulated with acetic acid. Cadmium sulphide is precipitated, and for the purpose of obtaining a precipitate better suited for the subsequent operations, the cadmium sulphide is converted into copper sulphide by the addition of a concentrated mixture of copper sulphate solution and sulphuric acid. This is then filtered off, ignited in platinum to copper oxide, weighed, and the sulphur originally present obtained by calculation. The author gives details as to the exact method of manipulation he employs, and shows that the results obtainable are very accurate.

The *Colliery Guardian* has published, in serial form, a full translation of L. Campredon's memoir \* on the determination of sulphur in iron and steel.

**Determination of Chromium.**—J. Spüller † and A. Brenner have modified the method they formerly used for the determination of chromium in ferro-chrome and in chrome steel, and adopt the following method :—In the case of ferro-chrome, 0·35 grammes is mixed in a silver dish with 2 grammes of caustic soda, as dry as possible, and then 4 grammes of sodium peroxide is scattered over the mixture as a cover. It is then heated, the burner being removed as soon as the mass begins to fuse. In consequence of the reactions taking place, the fusion proceeds of itself, and the mass should be stirred and heated until the whole is in quiet fusion. As soon as the first reaction is over, the dish should be again heated somewhat strongly. After another ten minutes of fusion, 5 grammes of sodium peroxide should be added carefully, and the temperature increased until the whole mass is thoroughly thin-fluid. After another thirty minutes a fresh quantity of 5 grammes of sodium peroxide is added. If the original sample had been sufficiently finely powdered the oxidation should now be complete. A further quantity of 5 grammes of sodium peroxide is then stirred in and the burner removed. The fused mass is cooled down to 80° or 90° C., and the dish is partially immersed in cold water, and water allowed to come in contact with the fused material. A rapid reaction ensues, the excess of sodium peroxide undergoing decomposition. In a few seconds the dish is entirely immersed in the water, which is contained in a porcelain dish. After one or two minutes the solution is complete, instead of taking an hour as formerly required.

\* *Revue Universelle des Mines*, vol. xxxv. 233-264; vol. xxxvi. 1-94, 168-219.

† *Stahl und Eisen*, vol. xvii. pp. 101-102.

The further treatment consists in removing the silver dish, decomposing any unreduced manganate or permanganate by the addition of some sodium peroxide, warming the solution, passing carbon dioxide through it for half-an-hour, diluting to 1 litre, filtering and then titrating the chromic acid contained in 250 cubic centimetres of the filtrate by the Schwartz method, as described in Fresenius' text-book. A little permanganate may be used to decompose any sodium manganate that may be colouring the solution green, the excess being decomposed by the permanganate as stated.

In the case of chrome steel, 2 grammes is dissolved in 20 c.c. of concentrated hydrochloric acid in a porcelain dish, heating this, when 10 c.c. of concentrated sulphuric acid mixed with an equal volume of water is added, the solution evaporated, and the excess of sulphuric acid evaporated off. The residue is transferred to a silver dish mixed with about 2 grammes of dry sodium hydrate, covered over with 5 grammes of sodium peroxide and then heated, much as in the case of the ferro-chrome, with occasional additions of sodium peroxide. After extraction, the solution is diluted to half a litre only, filtered, and one-half of the filtrate titrated. In the case of chrome steel the authors use, however, the Zulkowsky method rather than that of Schwartz. In this 250 c.c. of the filtrate is charged into a high narrow beaker, 10 c.c. of a 10 per cent. solution of potassium iodide is added, and then covering over with a clock-glass as carefully as possible, hydrochloric acid of 1·12 specific gravity is carefully added, the authors using the so-called "medical" hydrochloric acid, as concentrated hydrochloric acid always contains chlorine. When an acid reaction results, the addition of acid ceases. At the same time 20 c.c. of a potassium bichromate solution containing 0·9833 gramme of  $K_2Cr_2O_7$  to the litre is diluted to 250 c.c., 10 c.c. of the 10 per cent. potassium iodide solution is added, and then hydrochloric acid as before until an acid reaction results. Both samples are allowed to stand in the dark for fifteen minutes, and are then titrated, after the addition of starch, with a hyposulphite solution containing about 4·96 grammes of  $Na_2S_2O_3$  in the litre. The method is equally applicable to nickel-chrome steel.

In the determination of chromium by the Peterson \* method, use is made of the fact that chrome irons dissolve readily when finely powdered in dilute sulphuric acid. The hydrocarbons evolved in this solution are decomposed in the cold by a concentrated solution of potassium

\* Glückauf, vol. xxxiii. p. 89.

permanganate. The ferric sulphate is reduced in the usual manner by means of zinc, the solution is strongly diluted, and the iron determined by means of a standard solution of potassium permanganate. After the titration of the iron the chromic oxide present in the sulphuric acid solution is converted into chromic acid by a further addition, drop by drop, of permanganate solution. The end of this reaction is shown by the permanent formation of the hydrate of manganese peroxide. After filtering the cold solution, a weighed quantity of ferrous ammonium sulphate is added to convert the chromic acid to chromic oxide, when the excess of the ferrous salt is titrated back by permanganate. The quantity of the double salt required to convert the chromic acid into chromic oxide is a measure of the quantity of chromium present.

**Determination of Nickel.**—According to H. Brearley \* a gramme of steel is dissolved in 20 c.c. of nitric acid (sp. gr. 1·2), in a 1100 c.c. beaker, cooled, treated with dilute ammonia until slight precipitation ensues, then with hydrochloric acid until again clear; to this are added 70 c.c. of strong acetic acid, 950 c.c. or so of hot water, and 50 to 70 c.c. of ammonium acetate made by neutralising acetic acid with ammonia. The whole is boiled and made up to a litre, and half this is filtered hot, cooled, rendered alkaline with ammonia, and mixed with 2 c.c. of a solution containing 20 grammes of potassium iodide per litre, and 2 c.c. of a solution containing 2·5 grammes of silver nitrate per litre; a solution of potassium cyanide (4·5 grammes per litre, and standardised against standard nickel) is then run in until the silver iodide dissolves and the solution is clear. Tungsten and manganese do not interfere, and the coloration, due to chromium, is overcome by boiling the iron precipitate for half-an-hour. Copper has to be separated from the solution containing it and the nickel by means of sulphuretted hydrogen or sodium hyposulphite. With regard to procedure, adding the acetate to the hot solution is advantageous, since, in the presence of 70 to 100 c.c. of acetic acid, the precipitate does not appear before 85°-90°, but immediate precipitation should be avoided, as it causes low results. For filtering, fibrous asbestos, on a perforated plate 1½ inch in diameter, is found expedient; the tip of the funnel must be flat, and until in use the space below the perforated plate must be kept full of water, which is completely displaced by the first 300 c.c. of solution.

\* *Chemical News*, vol. lxxiv. pp. 16-17.

**Determination of Aluminium.**—F. A. Gooch and F. S. Havens \* have experimented on the separation of aluminium from iron with favourable results by taking advantage of the fact that hydrous aluminium chloride,  $\text{AlCl}_3 \cdot 6\text{H}_2\text{O}$ , is very slightly soluble in strong hydrochloric acid, while ferric chloride is extremely soluble. To diminish the solubility of the former salt anhydrous ether was mixed in equal parts with the strongest hydrochloric acid. More ether must be used if more than small amounts of iron are present. To determine the aluminium, the chloride is either turned into hydrate and weighed after ignition, or it is ignited direct and weighed as oxide. In the latter case, the precipitate should be covered with a layer of mercuric oxide. Some test experiments gave good results.

**The Analysis of Ferro-Silicon and Silico-Spiegel.**—G. T. Dougherty † gives methods for estimating silicon, manganese, sulphur, phosphorus, and iron in ferro-silicon and silico-spiegel. For silicon, 1 gramme is digested with 40 c.c. of nitric acid for fifteen to sixty minutes, 7 c.c. of strong sulphuric acid added, and the solution is evaporated, after which 30 c.c. of water are added, boiled, filtered, and washed. The moist filter is burned. For manganese, 1 to  $1\frac{1}{2}$  gramme is dissolved at a gentle heat in 20 c.c. of nitric acid of 1·20 specific gravity, with the addition of a few drops of hydrochloric acid at intervals until only graphite remains. The solution is diluted up to 300 c.c., and the manganese determined in aliquot portions by titration. For sulphur, 2 to 5 grammes are treated with 20 c.c. of strong nitric acid, with a little potassium chlorate, and then with repeated additions of hydrochloric acid, in quantities stated by the author, after which the sulphur is precipitated as barium sulphate. For phosphorus, 1 gramme is taken and dissolved in nitric acid with the addition of hydrochloric acid, and from the solution, after addition of potassium permanganate, ferrous sulphate, and ammonia, the phosphorus is separated by molybdate. The precipitate is redissolved, reduced by zinc, and titrated with permanganate. The iron in 1 gramme dissolved with nitric and hydrochloric acids is determined by titration with bichromate, and the carbon is determined by difference.

C. B. Murray and G. P. Maury ‡ give the following rapid method for the determination of silicon in silico-spiegel and ferro-silicon :—The

\* *American Journal of Science*, vol. ii. pp. 416-420.

† *Iron Age*, vol. lix. No. 11, p. 6.

‡ *American Chemical Society Journal*, XIX. ii. 1897.

sample should be in a very fine state of subdivision, so that it will pass through a sieve made of bolting-cloth. Half a gramme of the sample is placed in a porcelain or platinum dish; 50 c.c. water, 10 c.c. hydrochloric acid (1·20 sp. gr.), and 12 c.c. sulphuric acid (one part sulphuric acid, 1·84 sp. gr., to three parts water) are poured on it; heat until copious fumes of sulphuric acid are given off. Allow the dish to cool, so that there will be no sputtering when taken up with acid. When cool, add about 10 c.c. hydrochloric acid, heat to soften the sulphate of iron, add about 75 c.c. water, and bring to a boil. Discontinue the heating and note whether there is any effervescence when boiling ceases. If there is, the liquid must be evaporated until copious fumes of sulphuric acid are given off again, then taken up as before directed. Filter at once, wash thoroughly with hydrochloric acid (1 : 1) and hot water, ignite in a platinum crucible, and weigh. Add a few drops of sulphuric acid and enough hydrofluoric acid to dissolve the silica. Evaporate to dryness, heat to decompose the sulphates, cool, and weigh. The difference in the two weights is silica, which can be calculated to silicon. The whole operation can be accomplished in thirty minutes.

**Determination of Oxide.**—T. Tonnelé and R. B. Carnahan \* give the results of an investigation on the determination of oxide present in iron and steel. Four methods are in use, and these are:—(1) Ledebur's method of ignition in hydrogen and collection of the water in phosphoric anhydride; (2) volatilisation of the iron in chlorine; (3) solution in bromine water; (4) solution in iodine water. In the three last methods, the residual oxide is weighed. The authors experimented with seven methods, in which various solutions of iodine, bromine, copper chloride, potassium chloride, and hydrochloric acid were used. Analyses of some twenty samples, with the results obtained by several of these methods, are given. The best results were obtained except in the case of open-hearth steels, with 100 c.c. of a 10 per cent. solution of copper-potassium chloride, containing 3 per cent. of pure bromine.

\* *Proceedings of the Engineers' Society of Western Pennsylvania*, vol. xii. pp. 295-301.

## II.—ANALYSIS OF IRON ORES AND SLAGS.

**Standardising Permanganate Solution.**—E. Riegler \* observes that the alterations which take place in potassium permanganate solutions necessitate frequently re-standardising. The author prepares a standard solution which does not require this, but remains constant in strength in the following way:—9.9654 grammes of chemically pure oxalic acid are dissolved in about 500 c.c. of water, 50 c.c. of concentrated sulphuric acid is added, the whole allowed to cool, and then made up to 1 litre with distilled water. Oxalic acid has frequently been recommended for use in standardising permanganate, but two difficulties are met with. In the first place, it is not altogether easy to prepare oxalic acid with a formula corresponding exactly to  $C_2O_4H_2 + 2aq.$ , and then again an oxalic acid solution alters in composition on being allowed to stand. This latter difficulty can be avoided, according to the author, by mixing it with an adequate quantity of sulphuric acid, in accordance with his suggestion. Each cubic centimetre of the oxalic acid solution thus prepared corresponds to exactly 0.005 gramme of potassium permanganate in agreement with the equation:  $5(C_2O_4H_2 + 2aq.) + 2KMnO_4 + 3H_2SO_4 = 10CO_2 + K_2SO_4 + 2MnSO_4 + 18H_2O$ .

To standardise the permanganate 20 c.c. of this oxalic acid solution is placed in a small flask, heated to boiling, and then the permanganate solution is added from a second burette very carefully, until the last drop produces the coloration. As the 20 c.c. of oxalic acid solution corresponding exactly to 100 grammes of potassium permanganate, by dividing the number of cubic centimetres of this solution by 100, the weight of the permanganate in 1 c.c. of its solution results. A solution of oxalic acid prepared in the above manner showed no alteration in the course of a year.

**Determination of Iron.**—B. Neumann † describes the electrolytic separation of iron from copper, from lead, from silver, from mercury, from cadmium, from gold, from bismuth, from cobalt and nickel, from zinc, from aluminium, and from chromium.

S. W. Parr ‡ advocates the use of sodium peroxide as a reagent for

\* *Zeitschrift für Analytische Chemie*, 1896, p. 522.

† *Theorie und Praxis der analytischen Elektrolyse der Metalle*. Halle: W. Knapp, 1897, p. 191.

‡ *American Chemical Society*, vol. xix. p. 4.

the third group in qualitative analysis as follows:—The precipitate obtained in the ordinary method by means of ammonium hydroxide and ammonium sulphide contains, as hydroxides and sulphides, iron, manganese, cobalt, nickel, aluminium, zinc, and chromium, and is brought into solution by means of 10 to 15 c.c. of concentrated nitric acid with heat. Nearly neutralise with sodium hydroxide, then sift in slowly with stirring sodium peroxide in excess, and boil. The precipitate contains iron, manganese, cobalt, and nickel, whilst the solution contains all the aluminium, zinc, and chromium. Iron precipitates as a very dense reddish-brown precipitate, the exact composition of which is being made a matter of investigation. The precipitation is complete, no re-solution being effected upon boiling. The filtration is performed with great facility. The precipitate is almost insoluble in concentrated nitric acid; soluble in dilute acids on heating. If phosphates are present, none are precipitated with the iron, but all pass through and are found in the filtrate. Manganese behaves exactly as iron, precipitating presumably as the hydrated dioxide  $MnO_2 \cdot xH_2O$ , having all the properties of that compound as to colour, solubility, &c. Similarly, also, phosphates are not precipitated.

**Determination of Phosphoric Acid.**—O. Böttcher \* describes Wagner's method for the determination of the soluble phosphoric acid contained in basic slag. He does not approve of it, and describes a modification. The first portion of the analysis proceeds in the way described by Wagner, who recommended that 5 grammes of the finely-divided ground slag should be placed in a half-litre flask, which is then filled with dilute ammonium citrate solution of a temperature of 17.5° C. The flask is then closed with an indiarubber stopper, and placed at once in a rotating apparatus which makes from thirty to forty revolutions per minute. In this it remains for half-an-hour. The mixture is then immediately filtered, and 50 cubic centimetres of the filtrate taken for analysis. The author then proceeds as follows:—The precipitation is effected in the usual way with molybdate solution, the precipitate filtered, washed a few times with 5 per cent. ammonia, and the wet filter ignited in a platinum crucible. The residue, after ignition, is dissolved in hydrochloric acid with the aid of heat, the solution diluted slightly and filtered through a small filter, the phosphoric acid being then determined by the citrate method. Instead of igniting the filter as above described, drying it at 120° will

\* *Chemiker Zeitung*, vol. xxi. pp. 168-169.

be found adequate, and the precipitate can be dissolved off the filter. This method gives accurate results.

In the precipitation of the phosphoric acid by the use of a citrate solution and magnesia mixture, no silica passes into the precipitate if the precipitation is effected rapidly and the subsequent filtration effected without delay. The silica only begins to pass into the magnesia precipitate if it is allowed to stand in contact with the solution for half-an-hour or more.

The "dilute citric solution" referred to in this abstract is produced by mixing two volumes of the concentrated citrate solution with three volumes of distilled water. This concentrated solution should contain in the litre exactly 27.93 grammes of NH<sub>3</sub>, and 150 grammes of pure crystallised citric acid. Details are also given as to the preparation of the molybdate solution and of the magnesia mixture used.

F. Mack and M. Passon \* consider the question of the determination of the phosphoric acid in basic slag. Of the phosphoric acid solution obtained by the aid of the Wagner solvent, 100 cubic centimetres is taken and placed in a long-necked flask of about a half-litre capacity, together with 10 cubic centimetres of concentrated sulphuric acid, 15 of nitric acid, and a drop of mercury. This is then boiled, and the boil continued until the solution has become colourless. After cooling, 20 cubic centimetres of a 10 per cent. solution of common salt is added to precipitate the mercury, and the contents of the flask is transferred, together with the wash-water, to a 200 cubic centimetre flask, which is then filled up to the mark. One hundred cubic centimetres of this solution is then mixed with a similar quantity of the usual ammonium citrate solution and 25 cubic centimetres of magnesia mixture, taking care to cool the solution completely before the latter is added. The remainder of the process does not differ from the ordinary citrate method. The method gives very satisfactory results, and is both easier to effect and more rapid than the molybdate modification; and further, no admixture of silica with the magnesia precipitate is possible in this method.

**Determination of Sulphur.**—Some two or three years ago J. J. Morgan † experimented with the method described by R. W. and A. J. Atkinson, but ultimately discarded it for the following reasons:—

(1.) The great difficulty experienced in obtaining a clear filtrate upon filtering the aqueous solution of the mixture. Even when

\* *Zeitschrift für angewandte Chemie*, 1896, p. 129.

† Communicated to the Secretary, February 10, 1897.

employing four and more of No. 589 Schleicher and Schüll's papers (black bands), the small quantity of oxide of iron accidentally thrown on to the filter invariably passed through.

(2.) Upon acidifying the filtrate with hydrochloric acid, previous to adding the barium chloride solution, a precipitate of silicic acid in every instance was thrown down.

No doubt his non-success was due to want of experience, and not to the method. One great advantage of the method is, that any sulphur present as barium and calcium sulphate is recorded.

As regards the aqua regia method of estimating sulphur in iron ores, for several years he has employed the following with highly satisfactory results :—Five grammes of the dried ore is dissolved in 60 c.c. of aqua regia (1 part nitric acid 1·42 sp. gr. to 3 hydrochloric acid), the solution evaporated to dryness, and baked for an hour or so on the hottest part of the plate. The dry mass is then dissolved in 50 c.c. hydrochloric acid, the solution reduced by gentle evaporation to one-half the original volume, and, after diluting, the insoluble residue filtered off. The filter and contents washed with hot dilute hydrochloric acid and cold water until free from  $\text{Fe}_2\text{Cl}_6$ , 20 c.c. of barium chloride solution (150 grammes  $\text{BaCl}_2 \cdot 2\text{H}_2\text{O}$  per litre) added to the filtrate (the volume of which should not exceed 250 c.c.), mixed, and allowed to stand overnight in the cold. The solution is then filtered cold, the precipitate washed with dilute hot hydrochloric acid and cold water, dried, ignited, and weighed.

The following are a few results :—

No.	Experiment I.		Mean.
	Per Cent.	Per Cent.	
1.	0·042	0·043	0·042
2.	0·060	0·060	0·060
3.	0·175	0·171	0·173
5.	0·013	0·010	0·0115

**The Analysis of Blast-Furnace Slag.**—J. M. Camp \* describes the method for analysing blast-furnace slag. An equal weight is taken from the test-mould sample of each flush of slag, crushed to pass a 40-mesh sieve, and then ground as finely as required in an

\* *Iron Age*, vol. lix. No. 4, pp. 4-5; *Proceedings of the Engineers' Society of Western Pennsylvania*, vol. xiii. pp. 18-26.

agate mortar grinding-machine. A magnet is used to remove metallic iron. One gramme of the sample is dissolved in a porcelain dish in 10 cubic centimetres of water and 10 of hydrochloric acid, with a few drops of nitric acid if much iron is present. The solution is evaporated to dryness, taken up with 3 cubic centimetres of hydrochloric acid, and again evaporated, then taken up with 20 cubic centimetres of hydrochloric acid and 40 of water. The silica is filtered off and ignited, any barium being neglected. The solution is heated to boiling, a slight excess of ammonia added, and boiled; then it is cooled and filtered to separate iron and alumina. Iron is separately determined in a second sample of a gramme dissolved in 20 cubic centimetres of hydrochloric acid and 30 of water. Whilst hot three drops of stannous chloride are added, and then diluted with cold water to 300 cubic centimetres. Ten cubic centimetres of mercuric chloride solution are added, and the solution is titrated with bichromate. Alumina is thus found by difference. The filtrate from which iron and alumina have been separated is heated to boiling, and 25 cubic centimetres of saturated ammonium oxalate solution and 10 of strong ammonia are added. After boiling and settling, the precipitate is filtered off, ignited, and weighed as lime. If much magnesia is present, due to dolomite used as flux, the lime is doubly precipitated as oxalate. The filtrate is cooled, slightly acidulated with hydrochloric acid, and 10 cubic centimetres of a 10 per cent. solution of sodium phosphate is added, and then gradually, with constant stirring, 50 cubic centimetres of strong ammonia. After stirring at intervals for two or three hours, the precipitate is collected, ignited, and weighed. Manganese may be determined by a colorimetric method.

Sulphur in slag is determined by dissolving 0.25 gramme of slag in a flask in 50 cubic centimetres of dilute hydrochloric acid in the presence of 5 grammes of pure zinc. The slag dissolves quickly, giving off sulphuretted hydrogen, of which the last traces are expelled by hydrogen from the solution of the zinc, and by boiling. The gas is passed into 10 cubic centimetres of an ammoniacal solution of cadmium chloride placed in a 1 by 10-inch test-tube, and filled three-quarters full with cold water. This solution is then titrated with iodine, using the same solution as used for determining sulphur in iron or steel. Phosphorus and alkalies are seldom determined, but a molybdate method for the former is described.

### III.—ANALYSIS OF FUEL.

**Coal Analysis.**—In the course of some experiments on the calorific value of coal, N. W. Lord and F. Haas\* used the liquid left in Mahler's calorimetric bomb for the determination of sulphur in the coal, using Mahler's method of titration with standard ammonia and methyl orange as an indicator. The proximate analyses and the assays of a number of coals are given.

According to L. Campredon,† when finely powdered coal-ash is heated with concentrated hydrochloric acid for fifteen or twenty hours, the whole of the phosphorus does not dissolve, and the proportion that remains in the residue is greater the higher the temperature to which the ash has been heated. It often amounts to 10 per cent., and may amount to as much as 25 per cent. of the total phosphorus present. In order to get the whole of the phosphorus into solution, the ash must be heated with five times its weight of a mixture of equal parts of potassium and sodium carbonates.

L. Campredon ‡ also gives the results of comparative tests made by the author on the ash of English coals.

R. S. Hale § gives the methods used by some twenty different observers for determining the moisture in coal, and also some methods for the proximate analysis. For drying the coal, temperatures from air drying up to 250° F. are prescribed, but as a rule the temperature used is about the boiling-point of water, and the time of heating about an hour. After that the coal frequently gains in weight. If moisture determinations are to be made, a standard method ought to be prescribed.

**The Analysis of Coke.**—G. C. Davis|| gives a method adopted for the analysis of coke. To determine moisture, 1 to 2 grammes are heated for an hour in a platinum dish at a temperature of 100° to 105° C. A second sample is heated for 3½ minutes over a Bunsen

\* *Transactions of the American Institute of Mining Engineers*, 1897, Chicago meeting (advance proof).

† *Journal of the Chemical Society*, vol. lxxii. p. 158.

‡ *Moniteur Industriel; Colliery Guardian*, vol. lxxiii. p. 267.

§ *Transactions of the American Society of Mechanical Engineers*, vol. xvii. pp. 593-607.

|| Paper read before the Foundrymen's Association, *Iron Age*, vol. lviii. pp. 718-719; *American Manufacturer*, vol. lix. p. 804.

flame and then  $3\frac{1}{2}$  minutes over a blast lamp. After cooling it is weighed to determine the moisture and volatile matter expelled. The latter seldom exceeds 2 per cent. This time of seven minutes is generally adopted as a standard. The second sample is again ignited until the carbon is burnt off, and the residue is weighed as ash. Moisture, volatile matter, fixed carbon, and ash are thus determined. The Eschka method is used for estimating sulphur. One gramme of coke is mixed with  $1\frac{1}{2}$  gramme of a mixture of two parts of calcined magnesia and one part of dry sodium carbonate, and covered with  $\frac{1}{4}$  gramme of the mixture in a platinum crucible. The mixture is fused, stirred, and then extracted with water. To the filtrate containing sodium salts bromine water is added, and 3 cubic centimetres of hydrochloric acid to decompose carbonates. After concentration, the sulphur is precipitated as barium sulphate, containing 13.76 per cent. of sulphur. Coke usually contains  $\frac{1}{2}$  to 2 per cent. of sulphur.

## STATISTICS.

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## I.—UNITED KINGDOM.

**Mineral Statistics.**—According to the official statistics of H.M. Inspectors of Mines,\* the total number of persons employed in and about all the mines of the United Kingdom during the year 1896 was 725,803, of whom 692,684 worked at the 3385 mines under the Coal Mines Act, and 33,119 at the 731 mines under the Metalliferous Mines Act. Compared with 1895, there is a decrease of 7600 persons at mines under the Coal Mines Act, and a decrease of 254 persons at mines under the Metalliferous Mines Act. Of the 692,684 persons working at mines under the Coal Mines Act, 557,026, or about 80 per cent., were employed below ground. Of the 135,658 surface workers, 4517, or about 3·3 per cent., were females. At the mines under the Metalliferous Mines Act, 19,299 persons, or about 58 per cent., worked below ground, and of the 13,820 surface workers, 597, or nearly 4·3 per cent., were females. The total output of minerals at mines under the Coal Mines Act was 208,503,868 tons, of which 195,351,951 were coal, 2,526,044 fireclay, 7,856,586 ironstone, 2,419,525 oil-shale, and 349,762 sundry minerals. Adding 9309 tons from open quarries, the total

\* "Summaries of Statistics relating to the Mines and Quarries in the United Kingdom," London, 1896.

output of coal was 195,361,260 tons, which exceeds by 5,708,698 tons the highest amount hitherto recorded, namely, that of 1895.

At the mines under the Coal Mines Act there were 849 separate fatal accidents, causing 1025 deaths. Compared with 1895 there is a decrease of nineteen in the number of accidents, and a decrease of seventeen in the number of deaths. At the mines under the Metalliferous Mines Act there were thirty-seven fatal accidents which caused forty deaths. Compared with 1895 there is a decrease of nine in the number of accidents, and fourteen in the number of deaths.

**Iron Trade Statistics.**—The British Iron Trade Association reports \* the production of iron and steel in the United Kingdom in 1896 to have been as follows:—

	Tons.
Total pig iron . . . . .	8,563,209
Average production per furnace . . . . .	23,654
Stocks of pig iron . . . . .	1,214,805
Bessemer steel ingots . . . . .	1,815,842
"    " rails . . . . .	817,476
"    " plates and angles . . . . .	42,104
"    " bars, &c. . . . .	257,231
"    " sleepers . . . . .	49,603 †
"    " blooms, &c. . . . .	317,607
"    " tires . . . . .	84,516
Open-hearth steel ingots, acid . . . . .	2,145,268
"    " basic . . . . .	172,287
"    " total . . . . .	2,317,555
"    " rails . . . . .	30,058
"    " plates and angles . . . . .	984,929
"    " bars, &c. . . . .	418,640
"    " blooms and billets . . . . .	368,156
"    " castings . . . . .	25,108
"    " tires, axles, and sleepers . . . . .	18,278
"    " total finished steel . . . . .	1,845,169

There were 362 furnaces in blast and 304 out of blast, making a total of 666 as compared with 344 furnaces in blast in 1895. Of the 101 existing converters, 60 were in operation and 41 unemployed in 1896. No new converters were built. Of 31 basic open-hearth furnaces, 25 were worked, 3 were idle, and 3 were being built. Of the 352 acid open-hearth furnaces, 262½ were worked, 71½ idle, and 18 were building.

\* *Iron and Coal Trades Review*, vol. liv. pp. 518-519, and 552.

† Given as 46,603 and 49,603 in two places.

**Imports and Exports.**—According to the Board of Trade Returns,\* the exports from the United Kingdom during 1895 and 1896 were as follows:—

Description.	1895.	1896.
Pig iron . . . . .	Tons. 866,568	Tons. 1,059,796
Hoops, sheets, and plates . . . . .	102,927	120,923
Bar, angle, bolt, and rod . . . . .	143,990	178,124
Railroad iron . . . . .	457,552	749,106
Wire . . . . .	42,220	56,368
Tin plates . . . . .	366,120	266,956
Cast and wrought . . . . .	288,864	366,540
Old iron . . . . .	97,100	127,345
Unwrought steel . . . . .	208,208	296,830
Steel and iron manufactures . . . . .	23,344	36,821

The imports for the same period were as follows: †—

Description.	1895.	1896.
Iron ores . . . . .	Tons. 4,450,311	Tons. 5,417,476
Bar, angle, bolt, and rod . . . . .	67,847	71,058
Unwrought steel . . . . .	10,862	17,491
Girders, beams, and pillars . . . . .	69,200	75,197
Unenumerated . . . . .	163,037	167,024
	310,946	330,770

**The Progress of the Iron Industry of the United Kingdom.**—O. Simmersbach ‡ deals with this at some length. He treats the subject historically, and gives a number of comparative statistics. Amongst others he gives the following:—

Country.	Production of Pig Iron.						
	1865.	1870.	1875.	1880.	1885.	1890.	1895.
United Kingdom	Tons. 4,819,254	Tons. 6,059,000	Tons. 6,365,462	Tons. 7,872,000	Tons. 7,366,667	Tons. 8,030,000	Tons. 7,826,714
United States	931,582	1,900,000	2,401,000	3,895,000	4,109,238	9,350,000	9,627,448
Germany	771,903	1,390,000	1,700,000	2,729,000	3,751,775	4,563,000	5,788,798
France	989,972	1,178,000	1,360,000	1,725,000	1,655,004	1,970,000	2,005,889

\* *Iron Trade Circular* (Rylands), 1897, p. 88.

† *Iron and Coal Trades Review*, vol. liv. p. 271.

‡ *Stahl und Eisen*, vol. xvii. pp. 264-270.

## II.—AUSTRALASIA.

**Coal-Mining in Tasmania.**—According to the report of the Secretary of Mines of Tasmania for the year ending June 1896, the Colony produces a small amount of coal, but the development of the coalfields is hindered by the difficulties of transport. The output of coal for 1895–96 was 36,274 tons, valued at £32,647, an increase over the production of the previous year of 5711 tons.

## III.—AUSTRIA-HUNGARY.

**Iron Trade Statistics.**—The Austrian official statistics for 1895 \* show the production during the year to have included :—

Description.	Metric Tons.	Increase over	Per Cent.
		1894.	
Coal . . . . .	9,722,679		1·56
Brown coal . . . . .	18,389,147		6·10
Graphite . . . . .	28,443		17·92
Iron ore . . . . .	1,384,911		14·01
Manganese ore . . . . .	4,352		13·91
Forge pig iron . . . . .	660,549		6·53
Foundry pig iron . . . . .	117,961		...

The latter shows a decrease of 3·55 per cent. on the year. No nickel or cobalt ores were mined during the year.

The total number of workpeople employed at all the mines and metallurgical works of Austria numbered 133,910, an increase of 318 as compared with the previous year. Of this total 8312 were employed in smelting works. The total value of the produce of the mines and metallurgical works was £10,170,000, an increase of £200,000 as compared with the previous year.

The coal coked amounted to 1,114,180 tons. The average return of coke was 65·78 per cent., the quantity produced being 732,856 tons. The production was about equally divided between Moravia and Silesia, except for 51,942 tons produced in Bohemia.

\* *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xliv. pp. 683–687, and 703–707.

**The Blast-Furnace Industry.**—F. Schuster \* considers the progress made in recent years by the pig iron industry of Austria. He shows that in part prohibitive import duties existed in the first part of the present century. The home industry made progress, especially in the Alpine districts, which were especially favoured by the nature of the ores they had available. Thus in 1852 the production of pig iron in Austria-Hungary had already risen to 226,616 tons, whilst the imports amounted to 11,403 tons and the exports to 153 tons. In this year negotiations took place with a view to Austria-Hungary joining the German Zollverein. These only led, however, to a treaty of commerce. In this year the production of pig iron in the countries of the German Customs Union, including Luxemburg, amounted to 258,860 tons. In 1894 the production of the Austria-Hungarian Monarchy was 1,072,300 tons, while the production of Germany and Luxemburg was just five times as much—5,380,039 tons. The causes of the slower progress made by the iron trade of Austria-Hungary are various, and are considered by the author to have been due in part to political and in part to natural causes. Austria, again, is poor in coking coal. Indeed, with the exception of the two small coal-basins near Rossitz and Müreschau, in only one district is there any great richness of caking coal. This is in the North Moravian-Silesian basin, but this unfortunately is at a considerable distance from the iron ore deposits. The first coke blast-furnace in Austria was erected in 1832 at Witkowitz. After dealing in general with some of the earlier efforts, the author proceeds to discuss *seriatim* the iron industry of the different divisions of the Empire.

*The Alpine Districts.*—The iron industry here is of great antiquity. There are three parallel series of ore deposits, and the country is rich in forests. Iron was worked in pre-Roman times, and since 712 the industry has proceeded without interruption. The riches of Styria in iron ore are renowned. The deposits are worked chiefly open-cast.

There is one blast-furnace of good size in blast at Donawitz near Leoben. This is 66 feet high, has an internal capacity of 12,714 cubic feet, and produces on the average about 170 tons of white pig iron a day, with a consumption of 0.86 ton of coke per ton of pig iron made. The fuel used is Westphalian and Lower Silesian coke. There are several smaller coke blast-furnaces as well as charcoal furnaces. A typical charcoal blast-furnace will have a capacity of 3545 cubic feet, a daily out-turn of 60 tons, and a consumption of 158 cubic feet of

\* *Stahl und Eisen*, vol. xvi. pp. 764-770.

charcoal per ton of white pig iron made. The Alpine districts produce principally Bessemer and forge pig iron, the latter being treated partly in the puddling furnaces, which use brown coal as fuel, and partly in acid and basic open-hearths. Foundry pig iron is made at several places.

*Central Bohemia.*—Up to the middle of the fifties, charcoal furnaces were the only ones employed, smelting chiefly the native red haematises and magnetites. The most important of all the iron ore deposits, and the one on which the iron ore industry of Bohemia at present chiefly rests, was not then worked on account of the character of the ore. These deposits at Nucic are known along their strike for five miles, and have an average thickness of over 16 feet, while in places the thickness reaches nearly 59 feet. The ores resemble both mineralogically and as far as their chemical composition is concerned the Cleveland ores, except that they are found in the Silurian and not in the Jurassic horizon. They are carbonates which in part have been converted into brown haematises. The first coke blast-furnace here was erected in 1856 at Kladno, which smelted the Nucic ores with coke made from Kladno coal. This coal, however, yielded only 29 per cent. of coke, and this contained as much as 24 per cent. of ash. Finally, Lower Silesian coal was added to the Kladno coal in coking, and the manganese-ferous Amberg ores to the Nucic ores, high as these are in sulphur and phosphorus. In their uncalcined condition the Silurian oolitic iron ores of the Nucic deposits contain 0·8 per cent. of sulphur, and this was reduced to 0·1 per cent. by washing the calcined ore in large tanks of water, the sulphur passing into solution as aluminium sulphate. This process is still in use at Kladno. Up to 1879, too, the calcined ores were treated with a solution of sulphurous acid, and later on with dilute hydrochloric acid for the removal of the phosphorus. Phosphate passed into solution, and the phosphorus was reduced to so low a percentage that puddled bar could be made from the ore. The introduction of the basic process rendered this phosphorus elimination unnecessary. The calcined Nucic ores contain up to 48 per cent. of iron and 2·7 of phosphorus, but only 0·1 of manganese. Coke ceased to be made from Kladno coal in 1887, and Lower Silesian and Westphalian coke was used instead. The extra cost of this led to the remodelling of the Kladno blast-furnace plant, and there were erected at these works three large coke blast-furnaces. The two first, erected in 1891 and 1894 respectively, were each provided with three Gödecke-Whitwell stoves, and the third blast-furnace, erected in 1896, with four

Cowper stoves. The coke used is about 0·9 ton per ton of pig iron made. The internal capacity of the furnaces varies from 9989 to 16,810 cubic feet, and their height from 64 to 72 feet. They each make from 90 to 120 tons of basic Bessemer pig iron in the twenty-four hours, which is passed direct in its fluid state to the steel-making plant. Here it is heated up for an hour in acid open-hearths, solid basic pig iron being also melted down in the molten metal, and subsequently treated in basic-lined converters. A similar system exists at the Königshof Steelworks. This works possesses three modern blast-furnaces and a fourth is being erected. Nucic ores are smelted at these works also. In 1895 the Prague Company (Kladno, &c.) made 80,178 tons of pig iron, and the Bohemian Company (Königshof, &c.) 106,270 tons. As far as the author is aware, the Bohemian ironworks are the only ones at which a mottled pig iron, almost free from manganese, is taken direct in its fluid condition from the blast-furnace to the converters. Mixers are useless in the treatment of this iron.

The Moravia-Silesia group of works comprise, in addition to a few small active charcoal furnaces, the ironworks at Witkowitz, Trzynietz, Blansko, Stefanau and Friedland. Despite the richness in caking coal of the Ostrau-Karwin district, the iron industry only began to flourish here when the smelting of the native ores began to be replaced by that of the richer spathic ores and brown haematites of Styria and Hungary, and the other richer ores that are now smelted. In the summer of 1879 the first basic blow made on the Continent of Europe was made at the Witkowitz Works. In 1895 these works made with five blast-furnaces 210,000 tons of pig iron; and with six furnaces in 1896, 240,000 tons. The cubic capacity of the blast-furnaces varies from 10,242 to 12,819 cubic feet, and their daily out-turn of white pig iron from 150 to 170 tons, or of foundry iron 130 tons. The consumption of coke per ton of pig iron made is for white pig iron, 0·9 ton, and for foundry pig iron, 1·05 ton. The other works above mentioned are also briefly described.

The blast-furnace plant in erection at Trieste is intended to use coal from the United Kingdom, and ores from Spain and Algiers. The coal as imported into Trieste is to be screened, the dust coked, and the remainder sold. The plant is to possess two large blast-furnaces, but only one is now being built. Foundry iron is to be the chief product. Of the imports of pig iron in 1895, amounting to 133,588 metric tons, 117,056 tons, or 88 per cent. was foundry iron. The author also briefly refers to the iron industry of Bosnia, to which

reference has already been made in this Journal, and then in conclusion draws attention to the fact that while in the Hungarian portion of the Austria-Hungarian Monarchy the iron industry has made rapid progress in recent years, the Austrian Empire still produces approximately the same percentage of the total out-turn, 65 per cent. in 1874 and 70 per cent. in 1894.

**Coke in Austria.**—R. Helmhacker \* gives some particulars of the coke industry in Austria, and mentions the places at which coke is made, with some particulars of prices, out-turns, &c. In 1894 in Silesia there was made 375,727 tons of coke in 660 ovens, in Moravia 304,085 tons in 419 ovens, and in Bohemia 54,093 tons in 220 ovens. Briquettes are also made in these districts.

**The Iron Industry of Hungary.**†—At the late Exhibition at Buda-Pest the iron industry of Hungary was well represented. The collieries at Salgó, Bánszállás, and Járdáuháza, it was shown, employ 800 workpeople, and yield about 240,000 tons of brown coal annually. Among other exhibits were ores from the mines at Dashegy, Rákos, Lucia, Ostromos, and Schmöllnitz. These ores are high in manganese, containing some 10 per cent., together with 40 per cent. of iron. They do not contain much sulphur or phosphorus. The production of these mines was in 1895 about 130,000 tons. The ores were sent to the blast-furnaces at Nyustya and Likér, but other ores were also smelted at these works. The original Likér Works possessed two blast-furnaces, but three other large furnaces have been in continuous work since 1895. The furnaces are connected by a wire ropeway, 8 miles in length, with the Rákos and Vashegy iron ore mines, by the aid of which 600 tons of ore can be forwarded daily to the blast-furnaces. These have a production of about 100,000 tons, and this is used entirely at the other works belonging to the same company at Salgó-Tarján and Ozd. The Ozd Works possesses eleven puddling furnaces. These are equipped with regenerators and gas-firing, and yield daily about 17½ tons of puddled iron. This is worked up by the aid of four steam-hammers and two trains of rolls. The open-hearth works possesses four gas-fired Batho furnaces, served by a travelling electric crane. Electric cranes are also in use at other works. At the Salgó-Tarján Steelworks there are three 8-ton basic converters, the blast being provided by

\* *Engineering and Mining Journal*, vol. lxii. pp. 441-442.

† *Stahl und Eisen*, vol. xvi. pp. 725-730, 779-781, 827-829.

a 750 horse-power engine, which yields per minute 7063 cubic feet of air at a pressure of two atmospheres. Basic bricks are made at this works. Other works are also described, a historical sketch being given of the rise and progress of the Diósgyör Works, which had its origin in a furnace and forges built in 1765 by H. Frazola for the smelting of the ores found in the Szinwa valley. The Diósgyör Works made the drills used in the rock-boring operation in connection with the opening of a passage-way through the Iron Gates of the Danube. The contract required these drills to stand 90,000 blows, but they stood as many as 224,822, and even then were only removed in consequence of the actual wear. An iron bridge being built by this company for erection at Buda-Pest has had built into it 6000 tons of metal, and is the two-thousandth bridge constructed by this works. Mining in the Krasso county dates back for some couple of thousand years, and iron and other ores were mined there by the Romans. From 895 to 1552 this district belonged to Hungary, but from 1552 to 1718 it was in the possession of the Turks. The author describes the works and mines belonging to the Austria-Hungary States Railway, and draws attention to an electric installation which is being erected at the Szecsen coal-mines. It will yield 110,000 watts, and it is intended with this to work two pumps below ground, and also an electro-motor engine for traction purposes in the mines. This mine has a depth of 1508 feet below the adit. The seams mined are from 31 inches to 13 feet thick. At Anina the seams extend for 5·4 miles, and have a breadth of 1 mile, with a thickness of from 5 to 7 feet. The Reschitzta Steelworks and blast-furnace plant and other works are also passed in review, and the author then glances historically at the progress of the iron industry of Hungary in the past. Owing to the local conditions, Austria and Germany had made considerable advances in machine construction before Hungary entered the field, and practically supplied the whole of Hungary. Now, however, the reverse is the case, and in many details of the machinery market this foreign competition is now no longer possible, and Hungary supplies her own market, as the author shows. The value of the products made in Hungary in the period 1860 to 1874 is estimated at about £1,800,000, while in 1895 the out-turn was valued at £4,500,000.

## IV.—BELGIUM.

**Iron Trade Statistics.**—In the years 1894, 1895, and 1896, the production of iron and steel in Belgium was as follows:—

	1894.	1895.	1896.
Metric Tons.	Metric Tons.	Metric Tons.	
Foundry pig iron . . . . .	80,110	85,450	66,945
Forge pig iron . . . . .	378,045	329,651	364,640
Acid and basic pig iron . . . . .	360,442	414,034	501,195
Total pig iron . . . . .	818,597	829,135	932,780
Weld iron :—			
Sheets . . . . .	118,596	101,479	127,893
Other kinds . . . . .	334,694	351,901	391,964
Total weld iron . . . . .	453,290	453,380	519,857
Steel :—			
Ingots and castings . . . . .	405,661	455,550	598,755
Sheets, rails, &c. . . . .	341,318	392,332	498,765

In 1894 the weld iron rails are shown under the heading of "sheets," in 1895 under "other kinds." \*

**Coal Production.**—E. Harzé † has published two important statistical memoirs. Dealing with the Belgian industry from 1831 to 1890, and with the industry from that date up to the end of last year, they comprise eighty-five pages of carefully-digested figures of the utmost value for reference. One of the most striking features brought out is the great increase in the annual output of coal per miner, the results in each decade being as follows:—

Decades.	Annual Output per Miner. Tons.
1831-1840 . . . . .	92
1841-1850 . . . . .	112
1851-1860 . . . . .	123
1861-1870 . . . . .	138
1871-1880 . . . . .	146
1881-1890 . . . . .	175

For purposes of comparison, it may be noted that in the last decade (1881-1890) the corresponding figures in other countries were:—France, 200 tons; Prussia, 280 tons; Great Britain, 314 tons. On comparing the results of the last decade with those of the previous one, it appears that the annual output per miner had increased 20 per cent.

\* *Moniteur des Intérêts Matériels*, vol. xlvi. p. 412.

† *Annales des Mines de Belgique*, vol. i. Part iv.

in Belgium, 23 per cent. in France, 25 per cent. in Prussia, and 14 per cent. in Great Britain. On comparing the colliery accidents during the decade under consideration, it is seen that the proportion of lives lost per 10,000 miners was in Belgium 19·92, in France 18·53, in Prussia 29·34, and in Great Britain 19·36. Summarising briefly the results obtained in the Belgian collieries in 1895, it may be stated that the production was 20,457,604 tons ; 264 collieries were in operation ; there were employed 118,957 workpeople, 5203 horses, and 2177 steam-engines aggregating 139,061 horse-power. The average depth of the collieries worked was 1414 feet.

## V.—CANADA.

**Mineral Production.**—The advance statement of the Geological Survey of Canada shows a production for 1896 of 88,206 tons of iron ore, valued at £36,863, a decrease of 14,591 tons over the previous year. Of coal, 3,743,234 tons were mined in 1896, showing an increase of 229,738 tons since the previous year. The increase comes entirely from Nova Scotia, as British Columbia shows a decrease.\*

The official statistics † for Canada, just published for 1895, show as follows :—

Description.	1895.	1894.
Iron ore produced (tons)	102,797	109,991
Nickel ore produced (lbs.)	3,888,525	4,907,430
Petroleum, barrels	728,665	828,104
Imports in 1895 :—		
Pig iron	31,637	341,259
Charcoal pig iron	2,780	31,171
Scrap iron	643	4,347
Scrap steel	23,390	244,388
Ferro-manganese	193	8,514
Iron in slabs, blooms, puddled bars, &c.	...	67,321
Iron and steel goods manufactured	...	2,871,469
Iron and steel goods highly manufactured	...	5,130,816

R. Helmhacker ‡ briefly reviews the sources and supplies of mineral wealth in Canada. Iron ores, he says, are found everywhere, though they are but little mined as yet. At places, however, the ores found

\* *Engineering and Mining Journal*, vol. lxiii. p. 208.

† *Iron Age*, No. 6, vol. lxi. pp. 5-6.

‡ *Berg- und Hüttenmännische Zeitung*, vol. lvi. pp. 36-39.

are very rich, and in some cases are even exported to the United States. In Ontario very rich ores are found, both haematite and magnetite, along the coast of Lake Superior, in Thunder Bay, and near Port Arthur. The magnetites of Atikokan are considered the best, and these are exported. The rich ore deposits in Alberta, Vancouver Island, and on the mainland of British Columbia, are not yet mined. Manganese ores are mined in Nova Scotia and New Brunswick. Some graphite is also found. In coal, Canada is very rich. In 1879, 1,152,783 tons of 2000 lbs. were mined; in 1892 this quantity was 3,292,000 tons. The exports of coal, too, increase steadily. Some 3200 workpeople are employed at the collieries. Of coalfields two main subdivisions can be considered as existing—the eastern, with the St. Lawrence as its means of transport, and the western, sending its output to the Pacific. Weight for weight, the latter coal makes 25 per cent. more steam than that mined in Oregon and California. The Eastern coalfields yield true Carboniferous coals. In the Western field, in and around the Rocky Mountains, younger coals are met with. These belong to the Cretaceous horizon, and to the Laramie group, either the very Upper Cretaceous or the Lowest Eocene. In Alberta a considerable amount of coal-mining is carried on. In the Rocky Mountains, at Canmore, an anthracitic coal, with 87 per cent. of carbon, is mined. Other coal deposits are also mentioned.

Naphtha is also obtained, chiefly in Ontario, where there is a considerable output. At other places it is also known to exist.

**Nova Scotia Coal and Iron Industry.**—According to the annual report by E. Gilpin,\* jun., the coal output for the Province of Nova Scotia amounted to 2,287,574 tons in 1896. The London and Ferrona furnaces have been running, and 56,334 tons of iron ore were mined. Manganese mining was dull, only 125 tons being worked, but much prospecting has been done. Of coke about 60,000 tons were made, and of limestone as flux 26,000 tons were worked.

According to the *Canadian Mining Review*, the production of pig iron last year at the works of the Londonderry Iron Company in Nova Scotia amounted to 10,497 tons, and that of the Hamilton Blast-Furnace Company in Ontario to 25,270 tons. The output of the Acadia Colliery, Nova Scotia, was 199,303 tons of coal, and the production of coke reached 3773 tons, 795 miners being employed. The output of the Torbrook mines amounted to 8797 tons of iron ore.

\* *Engineering and Mining Journal*, vol. lxiii. pp. 65-66.

**Mineral Production of Ontario.**—The annual report of the Bureau of Mines, Ontario, for the year 1895 has been issued. Although Ontario is a province of large extent, and embraces within its boundaries geological formations from the lowest and oldest up to, but unfortunately not including, the Coal measures, and although evidences abound of the richness and variety of its mineral wealth, it is not yet possible to speak of it as a country possessing a well-established mining industry. The merchants and manufacturers of Hamilton have had the satisfaction at last of seeing their iron furnaces blown in and producing from native ores a pig iron of first-rate quality. It is nearly forty years since the last iron furnace in Ontario went out of blast, and during that long interval the iron mines of the country have been almost wholly idle. Indeed, so little interest was felt in iron ores during this period, that men had ceased to look for new deposits, and if discoveries were made, it was more as a result of accident than of prospecting with intent. The following is a statement of mineral production during the year 1895 :—

Product.	Quantity.	Value.
Nickel ore (lbs.) . . . . .	2,815 <sup>4</sup>	Dols. 404,861
Petroleum—		
Illuminating oil (imp. gals.) . . . . .	10,924,826	1,237,328
Lubricating oil     "     "     "     "	2,400,404	205,591
All other oils     "     "     "     "	7,081,717	285,308
Paraffin wax (lbs.) . . . . .	1,964,228	86,608
Fuel product . . . . .	...	79,589
Natural gas (cub. ft.) . . . . .	3,320,000	282,986

#### VI.—CAPE OF GOOD HOPE.

**Coal in South Africa.**—In the Cape of Good Hope the coal output in 1895 was 87,000 tons, and in Natal 158,000 tons. For last year it is expected to reach 300,000 tons, and the Cape has to import 200,000 tons from this country and the Transvaal. Partly on account of the report of a Committee appointed by the Cape Parliament in 1893, the railways have increased their consumption of coal, locally produced, at the expense of the imported coal. The prices of coal and costs of transport are considered in a recently published article.\*

\* *Engineering*, vol. lxiii. pp. 465-467.

## VII.—FRANCE.

**Mineral Statistics.**—The production\* of iron ore in France in 1895 was as follows:—

Description.	Production.	Proportion.
	Metric Tons.	Per Cent.
Oolitic iron ore . . . . .	3,352,000	91
Brown haematite . . . . .	77,000	2
Other hydrated ores . . . . .	78,000	2
Red haematite . . . . .	134,000	4
Spathic iron ore . . . . .	39,000	1
Total . . . . .	3,680,000	100

**Iron Trade Statistics.**—The production of iron and steel† in France during the year 1896 (provisional figures) and 1895 (definite figures) were as follows:—

Description.	1895.	1896.
	Metric Tons.	Metric Tons.
Forge pig iron . . . . .	1,516,168	1,840,341
Foundry pig iron . . . . .	489,721	493,361
Total pig iron . . . . .	2,005,889	2,333,702
Iron rails . . . . .	427	876
Merchant iron . . . . .	654,645	724,057
Plates . . . . .	88,599	89,710
Total wrought iron . . . . .	743,671	814,634
Steel rails . . . . .	160,417	170,675
Merchant steel . . . . .	386,168	501,062
Steel plates . . . . .	170,346	211,771
Total steel . . . . .	716,931	883,508
Beesemeyer ingots . . . . .	488,461	726,848
Open-hearth ingots . . . . .	330,493	401,921
Total steel ingots . . . . .	818,954	1,128,769

**Imports and Exports.**—The following table‡ shows the French iron trade imports and exports (in metric tons) during 1895 and 1896:—

Description.	Imports.		Exports.	
	1895.	1896.	1895.	1896.
Coke . . . . .	Tons.	Tons.	Tons.	Tons.
Iron ore . . . . .	1,412,950	1,422,130	84,580	62,510
Pig iron . . . . .	1,651,422	1,862,065	236,923	233,075
Wrought iron and steel . . . . .	36,984	22,193	161,309	195,308
	21,771	24,341	27,633	42,087

\* *Statistique de l'Industrie Minérale*, Paris, 1897; *Comité des Forges*, Bulletin No. 1151.

† *Ibid.*, Bulletin No. 1156.

‡ *Ibid.*, Bulletin No. 1142.

**Use of Steel Rails.**—In 1896 \* there were used by the different railway lines of France 77,104 tons of steel rails, as compared with 85,244, 110,609, and 129,338 tons in 1895, 1894, and 1893 respectively.

**Coal.**—Circular No. 1340 of the Comité Central des Houillères de France, which forms a quarto publication of more than 100 pages, contains extracts from the reports of the French Government mine inspectors on the state of mines and works last year in the coalfields of the Nord, Pas-de-Calais, Loire, Saône-et-Loire, Gard, Bouches-du-Rhône, Aveyron, Tarn, Hérault, and Haute-Saône.

In the Bulletin of the United States Department of Labour, there is a series of valuable reports by W. F. Willoughby on industrial communities. Especial prominence is given to the coal-mining industry, for reasons that are obvious. The situation of the mines renders the creation of special industrial centres in most cases a necessity, and the permanency of mining results in the growing up round the mines of a class of working-men among whom the pursuit of mining is hereditary. To represent this industry the Anzin Company is chosen as the largest in France, with a continuous existence of over a hundred years. Moreover, the character of the working-men's institutions that have developed there renders Anzin especially valuable as a place for investigation. The statistical tables given by the author, covering a long series of years, show that there has been a steady betterment of the condition of the Anzin coal-miners in almost every respect.

## VIII.—GERMANY.

**Production of Pig Iron.**—The production of pig iron in Germany, including Luxemburg, as estimated by the *Verein Deutscher Eisen- und Stahlindustrieller*, was in 1896 as follows:—

Description.	Metric Tons.	Per Cent. of Total.	
		1896.	1895.
Forge pig iron and spiegeleisen . . .	1,689,200	26·6	26·3
Beasemer pig iron . . . . .	515,352	8·1	7·7
Basic pig iron . . . . .	3,252,765	51·1	50·0
Foundry pig iron . . . . .	903,665	14·2	15·9

\* *Comité des Forges*, Bulletin No. 1141.

The total production thus amounted to 6,360,982 tons, but this does not include charcoal pig iron and scrap. The North-Western group of works produced 51·6 per cent. of the total out-turn.

The returns for 1895 show the production, including scrap, to have amounted to 5,464,501 tons, as compared with 5,380,038 in 1894.\*

**Iron Trade Statistics.**—According to official statistics,† there were in Germany, including Luxemburg, in 1895, 491 producing iron ore companies. These raised 12,349,600 tons of ore. The respective figures for 1894 were 537 and 12,392,065. The value per ton of ore was 3·47 shillings in 1893, 3·40 shillings in 1894, and 3·32 shillings in 1895. The workmen employed at the mines in 1895 numbered 33,556, as compared with 34,912 in 1894. Other statistics of the production are as follows:—

		1894.	1895.
Producing works, No.		102	104
Charcoal pig iron, metric tons		20,376	16,879
Total pig iron, tons		5,859,663	5,447,622
Ore smelted, tons		18,546,465	13,765,799
Workpeople employed		24,110	24,059
Existing blast-furnaces		258	268
Active blast-furnaces		208	212
Length of campaign, weeks		9,878	9,929

Of the total quantity of pig iron made in 1895, 855,797 tons was foundry iron and 3,373,223 tons Bessemer and basic pig iron. The forge pig iron made continues to drop steadily in quantity, its production in 1893 having been 1,370,298 tons as compared with 1,193,992 tons in 1895.

There were 1232 active foundries in 1895, employing 67,903 workpeople, and producing 1,154,835 tons of castings.

The works producing weld iron and steel numbered 208 in 1895, employing 38,190 workpeople, and producing 84,068 tons of semi-manufactures and 992,652 tons of shaped iron, rails, sheets, wire, and other manufactures. In 1894, 213 works produced 77,008 tons of semi-manufactures and 1,061,808 tons of manufactures, while in 1893 218 works made 95,796 tons of semi-manufactures and 1,078,065 tons of manufactures.

The works making ingot metal numbered in 1895 149, employing 75,080 workpeople, and producing 1,131,457 tons of semi-manufactures, such as ingots and billets, and 2,830,468 tons of manufactures, as com-

\* *Stahl und Eisen*, vol. xvii. p. 153.  
1897.—i.

† *Ibid.*, pp. 22-25.  
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pared with 146 works in 1894, producing 1,032,911 tons of semi-manufactures and 2,608,313 tons of manufactures. In 1893 these numbers were respectively 139, 931,569, and 2,231,873. The value shows a steady diminution, that of the semi-manufactures having fallen from 74·67 shillings per ton in 1893 to 70·99 in 1895, and that of the manufactures from 110·90 shillings per ton in 1893 to 106·15 in 1894, and 104·16 in 1895.

The quantity of coal produced in 1895 was 79,169,276 tons; in 1894 it was 76,741,127 tons; and in 1893, 73,852,330 tons. The quantity of brown coal raised was 24,788,363 tons in 1895, 22,064,575 in 1894, and 21,573,823 in 1893. The value per ton of the coal was 6·80 shillings in 1893, 6·68 in 1894, and 6·85 in 1895; and of the brown coal, 2·57, 2·44, and 2·38 shillings respectively. The total number of workpeople employed has been as follows:—

	1893.	1894.	1895.
Iron ore mining . . . . .	34,845	34,912	33,556
Blast-furnace plants . . . . .	24,201	24,110	24,059
Iron and steel works . . . . .	169,838	174,354	181,173

**Accidents in German Mining Districts.**—Details are given relating to the accidents in eight German mining districts in 1895. Altogether 40,616 are dealt with. Shown by the days of the week on which the accidents occurred, it appears that Tuesday, with 7110 of the total number, was the most dangerous day. The numbers for the other days of the week were as follows:—Wednesday, 6545; Thursday, 6595; Friday, 6596; Saturday, 6655; Sunday, 758; and Monday, 6357. Monday was the week-day most free from accidents in 1893 and 1894 as well as 1895. Other details relating to workmen's insurance are also given.\*

**The Dortmund Mining District.**—The production of coal in the Dortmund mining district in 1895 amounted to 41,145,744 tons, 154,702 workpeople being employed. In 1894 these totals were respectively 40,613,073 and 152,650. The output in 1895 thus shows an excess over that of 1894 of 532,671 tons, the increase in the number of workpeople being 2052.†

\* *Stahl und Eisen*, vol. xvi. pp. 1008–1014.

† *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xliv. p. 574.

**Mining Rights in Germany.**—An official report by C. Fortescue-Brickdale, the assistant-registrar of the Government Land Registry, on the systems of registration of title now in operation in Germany and Austria-Hungary, has been issued. The report gives full particulars with regard to mining rights.

**Exports of Munitions of War.**—The exports of cannons, rifles, shot and shell, powder and explosives, &c., from Germany have rapidly increased in recent years, and reached a value of £2,800,000 in 1895.\* The exports of high explosives have considerably more than doubled in the last four years, but the quantity of powder exported shows a marked diminution.

**Mineral Statistics of Upper Silesia.**—In 1895 † there were 54 collieries in Upper Silesia, with 903 engines of 82,553 horse-power, and 49,230 male and 3937 female workpeople. The material wound increased 5 per cent. as compared with the previous year, although the percentage of workpeople only increased by 0·3. The total wages amounted to rather less than £1,990,000; the average wage for workpeople over sixteen years of age amounted to £39, 6s. The coal raised amounted to 18,063,906 metric tons, an increase of 867,988 tons on the year, its value being rather less than £4,693,500.

The quantity of iron ore raised amounted to 475,694 tons. This was raised from 45 mines, employing 3142 workpeople. The average wage for workpeople over sixteen years of age was £25. The value of the iron ore raised was approximately £122,600.

Twenty-five coke blast-furnaces were in blast, producing 531,677 tons of pig iron, with an average consumption of coke amounting to 1·344 ton per ton of pig iron made. Charcoal pig iron was made at 2 blast-furnaces, 562 tons being made. At 25 foundries there were 39 cupolas, 16 reverberatories, and 4 open-hearths. These gave employment to 2155 workpeople. At 19 weld iron and ingot iron works there were 258 puddling furnaces, 138 welding furnaces, 44 heating furnaces, and 24 others; 72 steam-hammers, 6 presses, 7 cupolas, 2 acid and 4 basic converters, 17 open-hearths, and 65 furnaces of other kinds, together with 20 rolling-mills. The workpeople employed numbered 14,319, who earned a total wage amounting to £543,600. The total production amounted to 506,937 metric tons, of a total value of £2,769,000. Details are also given as to the manufacture of wire,

\* *Stahl und Eisen*, vol. xvi. p. 1030.

† *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xliv.

pipe, chains, nails, &c. The coke made amounted to 1,189,553 tons. The total number of workpeople employed at all the mines and works in Upper Silesia in 1895 amounted to 103,245.

## IX.—ITALY.

**Mineral Statistics.**—The Italian Minister of Agriculture and Industry has issued his statistical report on the mining industry. The statistics contained in the four last published reports tend to show, however, that the Italian mining industry makes but little progress. The value of the mineral production of the kingdom was as follows :—

Year.	£
1891 . . . . .	3,155,629
1892 . . . . .	2,972,072
1893 . . . . .	2,316,247
1894 . . . . .	2,081,704

The number of accidents was as follows :—

Year.	Accidents.	Killed.	Injured.
1891 . . . . .	152	64	145
1892 . . . . .	149	85	141
1893 . . . . .	139	75	126
1894 . . . . .	187	68	164

Calculated per 1000 miners employed, these figures represent :—

Year.	Accidents.	Killed.	Injured.
1891 . . . . .	2·61	1·09	2·49
1892 . . . . .	2·47	1·41	2·34
1893 . . . . .	2·46	1·33	2·23
1894 . . . . .	3·59	1·30	3·15

In 1894 the output of mineral fuel amounted to 327,576 tons. The centre of the industry is the San Giovanni Valdarno basin, where seven mines produced 152,225 tons of brown coal. The mines ranking next in importance are those of Spoleto with an output of 54,823 tons. The remainder of the supply was obtained from the Tuscan Maremma, from the Gonnesa basin in Sardinia, and from the Pulli mine at Valdegno. In 1895 the production of briquettes amounted to 431,300 tons, the industry affording employment to 500 workmen.

Of iron ore 176,393 tons were shipped from Elba in 1894, and 5810 tons of manganiferous iron ores were obtained from the Monte Argentario mine. Six blast-furnaces were in operation, and produced 10,329 tons of pig iron. Tin-plates were made at two works at Piombino and Darfo, their out-turns being 2750 and 3000 tons respectively.

The metallurgical statistics for 1895, published in the *Rassegna Mineraria* of January 11th, show that the production of pig iron was 9213 tons, 853 workmen being employed in the industry. There were also produced 163,824 tons of wrought iron and 50,314 tons of steel.

**The Elba Iron Ore Mines.**—A recent report \* gives the terms that were offered in January last for the lease of the iron ore mines on the Island of Elba. The term is twenty years, with prolongation of five years. Follonica smelting-works, averaging a yearly loss of £3600, have to be worked. A deposit of £4000 before tendering and of £40,000 before working is required. The export is limited to 250,000 tons yearly. The annual rent is to be reduced a quarter after 2,000,000 tons, and a half after 4,000,000 tons are extracted. At least 40,000 tons annually must be sold to Italian industries, for which a royalty of 5d. per ton is to be paid.

## X.—JAPAN.

**Iron Trade Statistics.**—The total imports of iron and steel into Japan in 1895 were of the value of 10,489,189 yen, as compared with a value of 9,178,768 yen in the previous year. Among the various kinds of material imported the following were the most important :†—

Description.	Value of Imports, 1895.	Value of Imports, 1894.
	Yen.	Yen.
Bar iron . . . . .	2,085,684	1,339,033
Iron rails . . . . .	1,278,056	1,332,637
Railway material . . . . .	1,253,343	881,805
Rails . . . . .	926,531	1,209,205
Plates and sheets . . . . .	918,458	726,738
Pig iron . . . . .	673,795	743,552
Iron pipes . . . . .	604,753	484,086
Steel . . . . .	503,571	362,366
Tin-plate . . . . .	251,181	296,284
Telegraph wire . . . . .	206,714	142,214
Iron wire . . . . .	142,432	84,811

\* "Capitolato per l'affitto delle regie miniere dell' Isola d' Elba." Rome, 1897.

† *Deutsches Handelsarchiv*, 1896, p. 774; *Stahl und Eisen*, vol. xvii. pp. 36-37.

By far the largest part of the railway material, rails, pig iron, pipes, plates, and sheets were imported from the United Kingdom. On the other hand, iron nails, iron wire, and telegraph wire came almost entirely from Germany, though towards the end of the year large quantities of wire nails were imported from the United States. Bar iron came mostly from Belgium, the United Kingdom, and Germany. The quantities imported from these countries were valued as follows:—

Country.	1893.	1894.
	Yen.	Yen.
Belgium . . . .	987,164	410,006
United Kingdom . . . .	865,960	571,703
Germany . . . .	254,825	340,681

It is pointed out that the imports from the United Kingdom probably include also considerable quantities of Belgian and German iron.

A pamphlet by R. P. Porter has recently been issued dealing with his investigations on trade in Japan. In the chapter dealing with the iron and steel industries it is stated that much activity is being displayed in that direction, and a Government foundry and machine-shop has been established. There is a large supply of coal, nearly 1500 mines being open, but iron ores are not abundant, although it has been estimated that nearly sixteen million tons are available. In 1894 there were made 15,760 tons of pig iron, 4815 tons of wrought iron, and 932 tons of steel.\*

The resources, industries, and markets of Japan, especially in relation to British trade, rails, locomotives, iron ore, and coal are discussed.†

## XI.—RUSSIA.

**Mining Statistics.**—The official returns of the mining and metallurgical industries of the empire for 1894 have been published (March 1896) by the Ministry of Public Domains‡ in a quarto volume of over 420 pages, giving detailed information respecting thirty industries. The following table gives the chief items of the production:—

\* Through the *Iron Trade Review*, vol. xxx. No. 9, pp. 17-18.

† *Iron and Coal Trades Review*, Supplement, April 9, 1897.

‡ *Shornik Statisticheskikh Svedeniy o Jorozabodckoi Promyshlennosti Rossii v. 1894, zavodskom godou.*

Minerals.	1894.		1893.	
	Production.	Value.	Production.	Value.
	Poods.	Roubles.	Poods.	Roubles.
Gold . . . . .	2,621	52,238,000	2,739	54,674,275
Silver . . . . .	477	568,000	580	691,740
Platinum . . . . .	318	2,226,000	311	2,293,077
Lead . . . . .	45,367	90,000	51,517	117,300
Copper . . . . .	330,213	3,302,000	333,508	3,966,314
Zinc . . . . .	306,113	918,339	274,774	1,071,510
Tin . . . . .	240	3,600	415	6,253
Mercury . . . . .	11,965	383,000	12,271	551,210
Pig iron . . . . .	81,347,077	85,500,000	70,140,559	47,750,000
Manganese ore . . . . .	14,863,798	1,227,000	16,399,352	1,672,749
Chrome iron ore . . . . .	460,138	46,900	890,429	87,753
Iron pyrites . . . . .	1,208,878	120,000	993,328	128,000
Cobalt ore . . . . .	557	...	192	
Coal . . . . .	534,941,429	28,684,000	464,818,293	23,063,000
Naphtha . . . . .	315,113,090	9,792,000	353,522,082	6,954,627
Salt . . . . .	82,675,105	4,308,000	82,482,037	5,580,584
Asphalt . . . . .	980,120	441,056	911,200	287,000
Mineral tar . . . . .	239,273	...	103,600	4,149
Graphite . . . . .	...	...	19,000	38,000
Asbestos . . . . .	34,827	8,500	64,654	17,089
Sulphur . . . . .	90	45	35,975	18,000
Glauber salt . . . . .	245,067	72,000	307,636	91,885
Chiuia clay . . . . .	472,654	76,000	195,201	32,121
Phosphates . . . . .	859,120	79,200	836,755	92,485
Total . . . . .	...	190,083,640	...	149,169,121

There were altogether 465,990 men occupied in the mining and metallurgical industries during 1894. The number of fatal accidents was 371 ; altogether 8602 men suffered injuries from accidents in mines and works. In iron mines there were engaged 32,961 workmen ; in coal mines, 51,161 ; and in ironworks, 210,691.

**The Iron Trade.**—The production of the private ironworks in Russia in 1895 was as follows :\*—

District.	Pig Iron.	Wrought Iron.	Steel.
	Metric Tons.	Metric Tons.	Metric Tons.
North . . . . .	700	41,062	94,120
Ural . . . . .	478,673	227,613	47,549
Central . . . . .	125,810	46,292	59,839
South . . . . .	550,437	41,658	256,842
South-west . . . . .	3,538	1,793	...
Weichsel . . . . .	184,527	63,524	107,509
Total . . . . .	1,343,685	421,942	565,859

\* *Deutsches Handelsarchiv*, September 1896 ; *Stahl und Eisen*, vol. xvi. p. 842.

The production of the State ironworks—not yet definitely known—being assumed to have been the same as in 1894, the production in the Russian empire would have been as follows:—

Description.	1895.	1894.	1893.
Pig iron . . . . .	Metric Tons. 1,454,298	Metric Tons. 1,312,760	Metric Tons. 1,160,737
Wrought iron . . . . .	464,810	459,206	436,000
Steel . . . . .	574,112	492,878	390,000

The production of coal in 1895 was about 9,725,000 tons, as compared with 8,648,640 in 1894 and 7,551,180 in 1893. The output of petroleum in 1895 is estimated at 5,300,000 tons, as compared with 5,174,421 tons in 1894. The imports into Russia in 1895 included:—

	Metric Tons.
Iron and steel, unworked . . . . .	300,252
Iron and steel manufactures . . . . .	33,350
Machinery and apparatus . . . . .	97,723
Total . . . . .	431,325

In addition, 132,791 tons of pig iron were also imported. The consumption of pig iron per head of population amounted in 1895 to 41·16 lbs.

**Iron and Steel at the Nijnii Exhibition.**—N. Verestchaguin has published a comparison between the position of the Russian iron and steel industries in 1896 and 1882 as illustrated by the Moscow and Nijnii Exhibitions of 1882 and 1896. The progress made in Russia as compared with that of other countries is seen in the following table:—

Country.	Production of Pig Iron in Million Poods.*	Production per Inhabitant in Poods.	Consumption per Inhabitant in Poods.
Great Britain . . .	1882. 526	1894. 450	1894-95. 11·4
United States . . .	286	412	6·6
Germany . . .	201	339	6·4
France . . .	124	127	5·4
Russia	28	80	3·2
Austria-Hungary . .	33	60	1·06
Belgium . . .	44	50	1·50
Sweden . . .	26	28	6·6
Spain . . .	7	16	2·9
			1·6

\* A pood=36·113 lbs., or 1 million poods=16·381 metric tons.

These figures show that although in its iron production Russia now stands fifth, at 5 per cent. of the world's total production, still it stands last in its production and consumption per inhabitant. In 1882 these last items were 0·28 and 0·60 respectively. It is interesting to note that the imports of iron (reducing machinery and manufactured iron and steel to their equivalent in pig iron) had increased from 35,000,000 poods in 1882 to 47,500,000 in 1894. The following figures give the imports (in poods) of iron and steel during 1882, 1884, 1887, 1891, and 1894 :—

Description.	1882.	1884.	1887.	1891.	1894.
Sheet, boiler-plate, and other rolled iron }	2,158,117	2,342,369	1,184,697	1,246,758	4,825,005
Bar iron, blooms, mill-bars, &c. . }	5,400,275	3,954,402	2,206,173	2,486,804	6,739,619
Iron rails . . .	55,115	10,800	6,388	27,186	94,696
Steel rails . . .	297,550	168,434	17,569	177,950	554,478
Steel plates, blooms, and scrap . . }	265,609	267,234	309,291	483,815	1,927,316
Steel bars . . .	19,279	75,575	140,426	226,040	500,819
Tin-plate . . .	44,344	14,030	391,142	1,667,867	1,269,266
Pig iron . . .	13,614,195	19,164,813	7,877,613	4,675,404	8,830,340
Machinery, boilers, &c.	1,910,333	1,609,054	1,399,786	2,193,270	4,146,448
Agricultural machinery, implements, &c. }	1,013,240	1,035,174	349,992	428,861	1,319,446

The greater part of the pig iron, tin-plate, and steel bars were imported from Great Britain, while Germany and Belgium supplied the larger portion of the bar iron, sheet iron, and steel plates and rails.

The author then proceeds to give a review of the customs policy and the chief alterations made in the tariff for iron and steel during the last thirty years.

The export of iron and steel from Russia is limited to about 300,000 poods, chiefly to Persia and China.

The following are the chief centres of the iron and steel industries in Russia :—

1. The Urals.—This is the oldest metallurgical district in Russia, and has already been under work for two hundred years. It comprises the famous iron ore deposits of Mounts Blagodat, Wisokhyi and Magnitnyi, not to mention many others. The iron ores are magnetic iron ore with 52-69 per cent. of iron, brown and spathic iron ore containing up to 60 per cent. of iron, and haematises with 60-68 per cent. of iron. Charcoal is exclusively employed in the manufacture of pig iron, and also

almost exclusively in the preparation of manufactured iron and steel. Thus, notwithstanding the vast and rich deposits of ores in the Urals, the further development of the industry is here absolutely dependent upon the possible supply of charcoal. It has, however, been lately estimated that the Urals comprise about 16,000,000 desatines\* of forest which could yield 160,000,000 poods of charcoal a year. This amount of charcoal would correspond to the same amount of pig iron, and if it be assumed that 50,000,000 poods of this pig iron would be converted into manufactured iron, we find the possible yield of the Urals to be 100,000,000 poods of pig iron. The production of the district has lately received an impetus by the erection of new ironworks in the Koutimsky and Wishersky estates, and in the Werhnystoursky region, where the "Ermak" Company have erected large blast-furnaces.

2. The Moscow region (the governments of Nijnii-Novgorod, Vladimir, Riazan, Tamboff, Penza, Moscow, Toula, Kalouga, and Orelloff) comprises about 100 mines, which are chiefly in the hands of small capitalists, and are not distinguished for the richness of their ore, so that some of the more southern works of this region smelt ore from the Krivoi Rog. The ores of the Moscow region are brown haematises and spherosiderites containing 40 to 50 per cent. of iron. The poor conditions of the forests and the bad quality of the local coals would not permit of increasing the yield of pig iron to more than 10,000,000 poods.

3. The south and south-western districts, with 13 iron mines in the Krivoi Rog, working haematises containing 60-68 per cent. of iron, and 12 mines in other parts yielding ore with 42 per cent. of iron. All the pig iron is smelted by coke, except at the Soulinsky Works, which employ anthracite. Unfortunately the Donetz coal contains a considerable amount of sulphur, the poorer kinds as much as 4 per cent. This is the youngest of the Russian iron regions. It is estimated that its production of pig iron will soon reach 60,000,000 poods.

4. Poland and the north-west provinces include 90-100 mines working spherosiderites and brown haematises containing 20-50 per cent. of iron. The production of pig iron in these districts has increased considerably since 1887, when the first high protective duty was put on foreign pig iron. There is also a tendency among the Polish works to re-smelt the rich slags and cinders remaining from the former old-fashioned processes of iron manufacture. The exportation of these

\* One desatine = 27 acres.

slags has been prohibited, and at the present time they are smelted to the amount of 12 per cent. of the whole material smelted. The reduction of the duty upon Silesian coke from 3 to 1½ kopecks (gold) per pood has also had a beneficent effect, as the Polish coals are not coking coals: 70 per cent. of the Polish pig iron is smelted with Silesian coke.

5. Siberia, notwithstanding its vast territory, possesses only 10 iron mines and 4 small ironworks, yielding less than 500,000 poods of pig iron. The financial position of these works prevents their enlarging their production. A thriving iron industry might, however, be established in the Kousnets coal basin (in the south-east corner of the government of Tomsk), where there are thick seams of coking coal in the neighbourhood of rich ores. Two companies have lately been started for erecting iron works in this district.

6. The Northern district, comprising the governments of Petersburg, Olonetz, and Courland, contains many deposits of excellent ores (haemmatites, magnetite and lake ore). The profusion of forest land and labour, together with easy means of transport by the numerous lakes and rivers, gives every condition for the further development of the iron industry in this region. An impetus has recently been given by the formation of the "Steel Company," with a capital of 10,000,000 roubles, for working the iron ore deposits of the government of Olonetz, and smelting about 5,000,000 poods of pig iron with local charcoal. Furthermore, blast-furnaces are being erected by the Poutiloff Works Company near Lake Ladoga, and by another private works on the River Sonna.

7. Finland has made no progress in its production of iron.

The production of pig iron in poods (iron and steel, machinery, &c., being converted into their equivalent weight of pig iron) in the different districts during the past few years is given in the following tables:—

Year.	Production of Pig Iron.						Total Production.
	Urals.	Moscow.	S. and S.W. Russia.	Poland and N.W. Russia.	Northern Russia.	Siberia.	
1882	18,463,000	3,421,000	1,653,000	2,870,000	100,000	380,000	1,350,000 28,237,000
1884	20,903,000	3,662,000	1,983,000	2,596,000	164,000	484,000	1,318,000 31,105,000
1887	23,426,000	4,374,000	4,158,000	3,933,000	117,000	402,000	979,000 37,389,000
1891	29,924,000	6,177,000	15,456,000	7,770,000	190,000	513,000	1,369,000 61,399,000
1895	33,638,000	7,680,000	33,818,000	11,603,000	245,000	529,000	1,272,000 88,785,000

Year.	Amount of Pig Iron Exported (including Iron and Steel).	Amount of Pig Iron Imported (including Iron and Steel).	Total Consumption.	Consumption per Inhabitant in Lbs.
1882 . .	762,000	34,993,000	62,468,000	24
1884 . .	598,000	36,581,000	67,088,000	25
1887 . .	855,000	18,899,000	55,433,000	19
1891 . .	725,000	19,987,000	80,551,000	26
1895 . .	...	47,602,000	136,387,000	45

Thus the production of pig iron more than doubled since 1882. It is noticeable that, notwithstanding this rapid growth of the home industry, the imports of iron and steel have simultaneously increased by 38 per cent. This is to be ascribed chiefly to the Government orders for railway material and to the increased activity of the army and navy departments.

The author then proceeds to compare the conditions of the Ural and South Russian iron centres. In abundance and purity the iron ores of the Urals can compete with those of the South. On the other hand, the Southern ironworks are able to smelt with Donetz coke and produce about 10,000 poods of pig iron per furnace per day, whilst the works of the Urals, working exclusively with charcoal, are not able to yield more than 2000 poods of iron per furnace. And yet the price of pig iron at the works is about the same in either case ; the fact being that the cost of charcoal (about 10 kopecks per pood) in the Urals will, under equal conditions of transport, always be cheaper than the Donetz coal. The Urals also have a great future market for their iron in Siberia. The great disadvantage under which the Ural ironworks labour is the absence of constant and proper means of transport to the central markets. Thus, in many cases, they are obliged to keep their stock, and therefore capital, stagnant for seven or eight months in the year for want of means of transport.

The progress made in the metallurgy of pig iron is fully illustrated by the fact that at the present day about 95 poods of pig iron are produced per 100 poods of coke, while in 1882 only 76 poods were yielded. As regards charcoal, the Ural works now yield 17 poods of pig iron per 20 poods of charcoal, while in 1882 only 13 to 15½ poods were produced. The yield of the blast-furnaces of the Urals has also been increased by 28 per cent.

Turning to the manufacture of iron and steel, it is seen that a corresponding progress has been made, thus—

Works.	1882.	1887.	1894.
Urals—	Poods.	Poods.	Poods.
Manufactured iron . . .	10,573,953	13,802,405	16,425,695
Steel . . .	1,509,830	2,328,231	3,923,848
Moscow—			
Manufactured iron . . .	2,744,010	1,844,841	4,127,892
Steel . . .	3,381,549	2,266,084	4,706,637
S. and S. W. Russia—			
Manufactured iron . . .	611,782	794,674	2,893,570
Steel . . .	1,467,810	2,488,743	15,958,318
Poland and N. W. Russia—			
Manufactured iron . . .	1,583,140	3,915,400	4,031,317
Steel . . .	3,319,183	3,048,327	7,889,441
N. Russia—			
Manufactured iron . . .	1,379,937	2,073,891	2,810,480
Steel . . .	5,524,739	3,509,711	8,759,451
Siberia—			
Manufactured iron . . .	178,113	155,315	313,887
Steel . . .	1,140	440	3,558
Finland—			
Manufactured iron . . .	1,000,370	465,378	700,000
Steel . . .	16,011	125,021	200,000
Total iron . . .	18,151,810	22,551,902	30,302,321
Total steel . . .	15,120,242	18,768,537	41,441,249

During the last twelve years the production of manufactured iron in Russia has increased by 70 per cent., while the production of steel has risen by 174 per cent.

**The Iron Industry of Russian Poland.**—J. Kowarsky \* observes that Poland being rich in fuel, metallurgical progress is greatly facilitated. The Dombrowa coal basin is a continuation of the coal deposits of Upper Silesia. In the past twenty-five years the annual production has increased from 300,000 tons to 3,700,000 from twenty collieries in active operation, giving employment to 14,000 workpeople. With regard to the outputs of the various collieries, the Sosnowice Company raised 1,600,000 tons of coal, and the Count Renard and the Warsaw Companies each about 500,000. The coal is not of a caking variety, and the ironworks of Poland have to fall back on Prussian or Austrian coke. The total production of ore is about 250,000 tons, half of which is raised in the government of Radom. The ores mined are mostly clay ironstone and brown haematite, with about 30 per cent. of iron in the raw state, and 35 per cent. when calcined. Polish blast-furnaces, therefore, rely in part on Russian ore from the Krivoi Rog. With regard to the ironworks, the Katherina Works with fourteen puddling furnaces produces annually 21,000 tons of malleable iron and manufactures. At the Barnkowa Works there are now eleven open-

\* *Stahl und Eisen*, vol. xvi. pp. 960-963.

hearts, and the annual out-turn is about 100,000 tons of ingots. A soft variety of ingot iron is made at the Katherina Works. The quantity produced is about 10,000 tons a year, and its analysis shows :—Carbon, 0·10; sulphur, 0·01; phosphorus, 0·02; and manganese, 0·50 per cent., with an elongation on 8 inches of 26 to 30 per cent., and a reduction of area of 40 to 60 per cent.

The kingdom of Poland produces about two-thirds of the quantity of pipes made in Russia. The only works in Poland which produces welded iron pipes is the Katherina Works, to which reference has already been made. At the present time there are three pipe-rolling works in Russia, and their out-turn is increasing enormously.

**The Moscow Coal Basin.**—According to official statistics,\* only eleven of the thirty-three existing collieries in the Lower Moscow coal-field were in operation in 1894. The total output of coal from this field in the years 1858 to 1893 amounted to 8,060,353 metric tons, or from 1860 onwards only 7·79 per cent. of the total production of coal in Russia. The maximum output of this field, 468,717 tons, was attained in 1879. The coal, notwithstanding its great geological age, closely resembles brown coal, and is among the worst coals in Russia. Indeed, 100 tons of this coal can be replaced by 58 tons of Douetz coal or by 38 tons of petroleum. The coal contains much ash and sulphur, and rapidly disintegrates by weathering. To improve the position of the coal-mining industry in this district, the coal should be subjected to mechanical preparation, and should be converted into briquettes. One ton of the coal from the Marawjewinski Colliery yielded 24,500 cubic feet of gas, and the coal from the Obidimski Colliery gave 18 per cent. of tar, as compared with 10 per cent. yielded by a good German coal.

**Oil Statistics.**—The Russian oil exports for 1896 from Batoum and Novorossisk amounted to : †—

	Barrels.
Residuum and crude oil . . . . .	199,300
Lubricating oil . . . . .	726,200
Distillate . . . . .	846,700
Illuminating oil . . . . .	5,481,400

The receipts of oil at Batoum in 1895 are given as 4,900,000 barrels of light or illuminating oils and 72,730 barrels of heavy or lubricating oils. Practically all this was received during the first ten months of the year, as the railway broke down in November. The reorganisation

\* *Berg- und Hüttenmännische Zeitung*, vol. lv. pp. 297–298.

† *American Manufacturer*, vol. lx. p. 195.

of the Baku Producers Association also affected the trade, but nevertheless the receipts of light oil were 9·15 per cent. heavier than in the previous year, whilst heavy oil decreased 29·5 per cent. The exports from Batoum, partly of oil in stock there, and including oil sent to inland markets, amounted to 5,982,600 barrels.\*

**The Iron Trade of Finland.**—Official statistics† show that the total value of the ores and products of metallurgical works and machine-shops in Finland in 1895 amounted to 22,373,898 Finnish marks (about £940,000), or 3,503,431 marks in excess of the value produced in the previous year. Amongst the output was the following:—

Description.	Value in Finnish Marks.	
	1895.	1894.
Lake and bog iron ores . . . . .	546,651	534,616
Iron ores mined . . . . .	12,000	...
Pig iron . . . . .	2,050,000	2,000,000
Bar iron, hammered . . . . .	850,000	900,000
Bar iron, rolled . . . . .	1,750,000	1,900,000
Ingot metal . . . . .	1,550,000	950,000
Black sheets, &c. . . . .	1,515,371	1,234,576
Products of private foundries and machine-shops . . . . .	11,279,051	8,957,366
Products of State foundries and machine-shops . . . . .	2,000,560	1,788,302

Iron ores had not been obtained by deep mining in Finland for a number of years before 1895, when the Poutiloff Company of St. Petersburg commenced mining on a considerable scale near Wälimäki. The ore is titaniferous magnetite, but does not yield more than 40 per cent. of iron. It is enriched by magnetic concentration, and is then shipped to the Russian works on the Lake of Ladoga. During 1895, 1906 tons of concentrates were produced. Of lake and bog iron ores 658,185 tons was obtained from 169 lakes, &c. In 1894 this production was 68,244 tons. The production of pig iron increased from 21,174 tons in 1894 to 23,220 tons in 1895. Thirteen furnaces were in blast in 1895 for 3113 days. In only one furnace was cold-blast used. The others used blast heated to from 100° to 350° C., and blown at a pressure of from 30 to 90 millimetres of mercury. Of malleable iron, 20,852 tons was made in 1895, as compared with 14,665 tons in 1874, an increase of 43 per cent. Two acid and one basic open-hearth furnaces are in use. These made, in 1895, 5390 tons of ingots, and 185 tons of castings, from 3552 tons of pig iron and 2541 tons of other iron. The

\* *American Manufacturer*, vol. lix. p. 554.

† *Stahl und Eisen*, vol. xvi. p. 1021.

puddling furnaces worked up 10,625 tons of pig iron and 206 of scrap, using 91 tons of coal and 80,029 cubic yards of wood as fuel. Altogether their out-turn amounted to 9457 tons. Details are also given which relate to the manufacture of other kinds of iron, and the yield of foundry products and machine-shops.

Dr. Leo\* observes that coke is not used in the Finland blast-furnaces. The largest producers among the blast-furnaces were those at Mökhö, 3845 tons; Strömsdal, 3660 tons; Tykö, 2151 tons; and Karttula, 2150 tons. The Högfors' furnace produced only 243 tons. The yield of iron from Swedish ores varied from 49·27 to 52·5 per cent. The Finnish ores yielded from 30·3 to 42 per cent. of iron. The production of malleable iron in 1894, 14,647 tons, represented an increase of 10 per cent. on the year. The old Stückofen was still in use at Kiminki and Koskeussaari, but the total output was only 47·3 tons of wrought iron. The rolling-mills rolled 4407·5 tons of ingots, with a consumption of 834 tons of coal and 1147·7 cubic metres of wood to 640·8 tons of sheets and 3337·3 tons of other sorts; 204·5 tons of scrap also resulted. The exports from Finland to Russia in 1894 included 266,744 poods of pig iron (1 pood = 36·113 lbs.), 386,002 poods of bar iron, and 236,334 poods of other kinds, including manufactures.

## XII.—SPAIN.

**The Iron Industry.**—According to the statistics collected by Don Roman Oriol, the production of iron ore in Spain in 1896 shows an increase of one million tons over that of the previous year. The production of the various provinces was as follows:—

Province.		1895.	1896.
Vizcaya . . . . .	Tons.	4,574,724	5,900,000
Santander . . . . .		448,286	530,000
Murcia . . . . .		164,453	300,000
Seville . . . . .		122,808	265,000
Almeria . . . . .		99,511	275,000
Oviedo . . . . .		59,253	60,000
Malaga . . . . .		17,503	38,000
Other Provinces . . . . .		27,801	40,000
<b>Totals . . . . .</b>		<b>5,514,839</b>	<b>6,808,000</b>

\* *Stahl und Eisen*, vol. xvi. p. 837; compare *Journal of the Iron and Steel Institute*, 1895, No. II. p. 622.

The increase shown in these returns is confirmed by the statistics published by the Spanish Customs, the export of iron ore being shown to have been as follows :—

Provinces.	Ports.	1895.	1896.
		Tons.	Tons.
Almeria . . . . .	Almeria . . . . .	4,760	55,591
Guipuzcoa . . . . .	Garrucha . . . . .	98,688	219,087
" . . . . .	Behobia . . . . .	8,380	13,870
Huelva . . . . .	Irun . . . . .	630	1,131
" . . . . .	Passajes . . . . .	..	440
Huelva . . . . .	Huelva . . . . .	1,551	20,774
Malaga . . . . .	Marbella . . . . .	38,329	37,679
" . . . . .	Cartagena . . . . .	133,353	277,836
Oviedo . . . . .	Aguilas . . . . .	24,510	17,868
Santander . . . . .	Gijon . . . . .	4,386	..
Seville . . . . .	Santander . . . . .	204,561	231,133
Vizcaya . . . . .	Castro Urdiales . . . . .	250,310	298,456
" . . . . .	Seville . . . . .	88,582	265,314
Valencia . . . . .	Bilbao . . . . .	4,354,133	4,798,283
Alicante . . . . .	Povena . . . . .	32,080	30,690
	Valencia . . . . .	4,000	..
	Totals . . . . .	5,248,192	6,268,152

The leading producer in Vizcaya is the Orconera Iron Ore Company, which in 1896 produced 956,033 tons. The Vizcaya Company mined 150,000 tons of iron ore, and in its Carvès coke-ovens made 88,700 tons of coke. In Asturias, the Fabrica de Mieres Company raised 25,000 tons of iron ore.

The production of iron and steel in Spain in 1896 was as follows :—

	Tons.
Pig iron . . . . .	246,326
Bessemer steel . . . . .	62,511
Open-hearth steel . . . . .	42,066
Finished iron and steel . . . . .	137,809

Of the 246,326 tons of pig iron made, only 23,805 tons were exported.

XIII.—*SWEDEN.*

**Iron Ore Production.**—Nils Kjellberg \* publishes an account of the production of iron ore and pig iron in Sweden. In 1870 the production was only 630,000 tons, but in 1894 this had risen to 1,927,000 tons. With the aid of graphic diagrams, the author shows that this increase in the output has taken place chiefly since 1891, when it amounted to less than one million. This appears to be almost solely due to the enormous increase in the output of the Norbotten and Kopparberg districts, the first of which has risen from a very small output indeed in 1891 to 658,000 tons in 1894; whilst the output of the Kopparberg district, which in 1870 was only 170,000 tons and in 1891 about 350,000, was in 1894 as much as 547,000 tons. Since 1870 there has, too, been an increase in the outputs of the Orebro, Westmanland, and Upsala districts; while in Stockholm and Gefleborg there has been a diminution in the output during this period, as the following table shows:—

District.	Production in	
	1870.	1894.
Orebro . . . . .	Metric Tons. 157,000	Metric Tons. 299,000
Westmanland . . . . .	93,000	206,000
Upsala . . . . .	32,000	63,000
Stockholm . . . . .	24,000	20,000
Gefleborg . . . . .	21,000	13,000

The pig iron production of Sweden from 1870 to 1894 is also shown graphically. The share taken by each district was as follows:—

District.	1870.		1894.	
	Per Cent.	Per Cent.	Per Cent.	Per Cent.
Kopparberg . . . . .	22·3	26·4		
Orebro . . . . .	29·0	25·4		
Gefleborg . . . . .	11·3	13·0		
Vermaland . . . . .	15·0	11·9		
Westmanland . . . . .	7·3	8·4		
Upsala . . . . .	3·7	4·7		

\* *Teknisk Tidskrift*, vol. xxvi. pp. 38-44.

**Coal-Mining.**—During 1895, the last year for which official returns are as yet available, 223,652 tons of coal were raised from the collieries in Sweden, as compared with 195,950 tons in 1894.

#### XIV.—SWITZERLAND.

**The Iron Trade.**—The iron trade imports of Switzerland included the following quantities in the years mentioned :—

Material.	1895.	1894.
	Metric Tons.	Metric Tons.
Pig iron and scrap . . . . .	62,054	72,845
Rails, bars, and shapes . . . . .	95,586	95,518
Castings . . . . .	9,798	12,995
Pipes . . . . .	5,973	5,214
Machinery . . . . .	11,350	10,229
Sheets . . . . .	12,497	11,999
Wrought iron wares . . . . .	11,366	9,932

Amongst other iron trade exports, dynamo machines to the value of £145,360 were exported from Switzerland in 1895, while of spinning machinery the quantity amounted to 5058 tons, as compared with 5152 tons in the previous year.

By far the largest iron trade importer into Switzerland is Germany. In shaped iron, Italy appeared as an important competitor in 1895 for the first time. On the whole, the imports from England appear to rather more than hold their own as compared with previous years.\*

\* *Stahl und Eisen*, vol. xvi. p. 746.

## XV.—UNITED STATES.

**Iron Trade Statistics.**—The total production of pig iron in the United States in 1896 was 8,623,127 tons, as compared with 9,446,308 tons in 1895. The make of Bessemer pig iron amounted to 4,654,955 tons, and that of basic pig iron to 336,403 tons. The production of charcoal pig iron was 310,244 tons, and that of spiegeleisen and ferro-manganese 131,940 tons.

The production of Bessemer steel in the United States has been as follows,\* Pennsylvania contributing the largest amount :—

	1896.	1895.	Decrease.
	Tons.	Tons.	Tons.
Total ingots . . .	3,919,906	4,909,128	989,222
Rails . . .	1,102,892	1,266,061	163,189

**Mineral Production.**—The *Engineering and Mining Journal* † has collected returns of the mineral production of the United States in 1896. The statistics include the following :—

	Metric Tons.
Coal, anthracite . . . . .	44,321,476
Coal, bituminous . . . . .	124,585,909
Coal, cannel . . . . .	49,587
Coal, total . . . . .	168,956,972
Coke . . . . .	9,395,809
Iron ore . . . . .	14,884,400
Pig iron . . . . .	8,761,120

According to the *Connellsville Courier*, the production of coke in the district in 1896 was 5,411,602 tons. Although this total represents a greatly decreased production, the year was a profitable one, as the price of coke was higher. By-product coke-ovens do not seem to be coming into use. Connellsville coalowners have thoroughly investigated the matter, but their opinions do not appear to be favourable to the experiment.

E. W. Parker gives some very suggestive figures in his statis-

\* *The Bulletin of the American Iron and Steel Association*, vol. xxxi. p. 44; *Engineering and Mining Journal*, vol. lxiii. pp. 208-209.

† Vol. lxiii. pp. 537, 629.

tical report on the production of coal in the United States. In 1868, when the world's production of coal was about 225,000,000 tons, the United States yielded but 14 per cent. The world's production is now 629,000,000 tons, and the share furnished by the United States is 30 per cent. Great Britain, whose mines in 1868 supplied more than 50 per cent. of the world's output, now barely exceeds the percentage of the United States.

The average number of coal-miners employed in the United States in 1895 was 382,879, and the average number of days they were at work was 195. The average price of coal at the mines was 4s. per ton of 2000 lbs. Based on the returns obtained from 425 mines, producing an aggregate of 34,335,000 tons, an attempt has been made to estimate the cost of coal-mining in the United States with the following results :—

	Dollars.
Wages paid miners per ton . . . . .	0·48
Total expenses per ton . . . . .	0·75
Selling price per ton . . . . .	0·96
Total wages paid miners . . . . .	16,672,040
Total expenses . . . . .	25,970,110
Total selling price . . . . .	32,661,750

These figures show that of the total expenses 64 per cent. is absorbed in wages paid to miners.

According to the statistical returns of the California State Mining Bureau (*Bulletin No. 8*), the production of coal in California in 1895 amounted to 79,859 tons. There were also produced 1740 tons of chrome iron ore, 2200 tons of magnesite, 880 tons of manganese ore, and 1,245,339 barrels of petroleum.

The seventh Biennial Report of the Inspector of Coal Mines of the State of Colorado contains some interesting particulars. The total production in 1896 amounted to 3,371,633 tons of coal and 324,694 tons of coke. One life was lost for 49,582 tons of coal mined. The proportion was abnormally raised by forty-nine lives having been lost in a single accident.

The Chief Inspector of Mines of Kentucky reports that the production of coal in the State during 1896 was as follows :—

	Tons.
Bituminous coal . . . . .	3,128,818
Cannel coal . . . . .	54,861
Total . . . . .	<u>3,183,479</u>

There was a decrease, compared with the previous year, of 0·8 per cent.

in the total. The average value of bituminous coal at the mine was 3s. per ton, and of cannel 10s. 6d. per ton.

The State Mine Inspector reports that the output of coal in Tennessee in 1896 amounted to 2,663,714 tons, as compared with 2,319,720 tons in the previous year. There were 64 mines producing, employing an aggregate of 6556 men. The total production of coke was 332,746 tons, 1367 coke-ovens being in operation. The average yield of the coal treated was 56·7 per cent. Great attention is paid to the washing of coal, 58 per cent. of the coal used for coke-making having been purified in this manner.

Advance statistics have been issued of the coal production of Illinois in 1896. Full details will be published in the fifteenth Annual Report of the Bureau of Labour Statistics. The number of mines amounted to 901, the coal production was 19,786,626 tons, and the number of workmen 37,032; 307 coalcutters were in use. The number of lives lost was 77, whilst 762 men were injured; 256,969 tons of coal were mined for every life lost.

**Convict Labour in Mines.**—The United States Department of Labour has published a report on convict labour. There are four plans followed in the employment of convicts: (1) the contract system, (2) the piecework system, (3) the public account system, and (4) the lease system. Convict labour is employed in coal-mining in Alabama, Kansas, Tennessee, and Texas (iron ore), the annual value of the work done being as follows:—

State.	Value in Dollars.	System.
Alabama . . . . .	622,463	Lease
Kansas . . . . .	92,624	Public account
Tennessee . . . . .	298,750	Lease
Texas . . . . .	4,000	Public account

In the lease system the penal institution leases the convicts to a contractor for a specified sum and for a fixed period, the lessee usually undertaking to clothe, feed, and maintain discipline among the prisoners during their work. In the public account system the institution works its own collieries.

**Iron Ore Mining in the Lake Superior District.**—The season of 1896 is second only to that of 1895 in the amount of ore shipped from

Lake Superior mines. The lack of demand cut down the shipments of Bessemer ores from a first estimate of 9,700,000 tons to something over 6,000,000 tons, but non-Bessemer ores have given a larger total than was expected. For last year the shipments of ore from the seven ports on the lake totalled up to 9,657,921 tons, of which 8,026,432 tons were received at Lake Erie ports, and about 1,300,000 tons at South Chicago. The ore carried by rail from the mines is probably about 300,000 tons.\*

Statistics of the production of the various ranges are as follows for 1896 and 1895 : †—

Mineral.	Tons in 1896.	Tons in 1895.
Marquette . . . .	2,604,221	2,097,838
Menominee . . . .	1,560,467	1,923,798
Gogebic . . . .	1,799,971	2,547,976
Vermilion . . . .	1,088,090	1,077,838
Mesabi . . . .	2,882,079	2,781,587
Totals . . . .	9,934,828	10,429,037

The importance of the improvements of navigation on the Great Lakes is shown by the fact that nearly thirty million tons passed through the Detroit River, where nearly all the tonnage of the lakes meet. The rate is estimated at 0·085 cent. per ton mile, whilst on trunk railway lines the rate is 0·45 to 0·60 cent. In 1896 no less than 16,239,061 tons of freight passed through the Sault Ste. Marie Canal, or more than twice as much as passed through the Suez Canal. Over 60 per cent. of the iron ore supply came from the Lake Superior district last year.‡

G. G. Tunnell § deals with lake transportation and the iron ore industry. In 1880 the output of the four States, New York, Pennsylvania, New Jersey, and Ohio, was 59·59 per cent. of the total of the United States, but this fell to 9·62 in 1895. It is pointed out,|| however, that many of the furnaces in these States are now out of blast, and new furnaces have been built farther east, so that it is really a case of migration.

\* *Iron Trade Review*, vol. xxix. No. 50, pp. 9-10.

† *The Bulletin of the American Iron and Steel Association*, vol. xxxi. p. 34.

‡ *Engineering and Mining Journal*, vol. lxiii. p. 134.

§ *Journal of Political Economy*, December 1896.

|| *Iron Trade Review*, vol. xxx. No. 1, pp. 6-7.

**Cost of Iron.**—G. H. Hall \* discusses the cost of iron as related to industrial enterprises, and traces some of the violent fluctuations of price in America. This is ascribed to the prevalent smallness of stocks, and it is recommended that the certificate or warrant system should be adopted.

Naturally much discussion has ensued † with regard to the proposed changes contemplated in the United States import duties. The works on the Atlantic seaboard object to an increase owing to the advantages enjoyed by those districts which draw cheap ores from the Lake Superior districts and from the Alabama deposits. Increased duties on wire, especially on high qualities used for wire rope, are also objected to, and exception is also taken to increase on raw material for making saws.

A letter from the American Iron and Steel Association, signed by B. F. Jones, J. Wharton, J. M. Swank, and A. Wheeler, to the Chairman of the Committee on Ways and Means has recently been published.‡ It strongly advocates the imposition of duties on imports of iron and steel, and expresses a preference for specific duties in place of *ad valorem* duties. A history of the tariff legislation is given from 1789 to the present date, and it is stated that prices have invariably declined under protective duties. The drawback on tin-plate should be abrogated.

A. E. Outerbridge, § in discussing the future of American industries, points out that great developments have occurred during the past year in the export trade of the United States, and of these a very large proportion consists of manufactured materials. This has been in spite of high rates for labour and carriage. Two years ago Alabama sent 250 tons of pig iron to England, and it is stated that since then large shipments have been made to England and Europe, and that there is an increasing trade in this direction. The increasing power in works is shown *inter alia* by one of the Duquesne furnaces, which in November 1896 made 572 tons of pig iron daily, with a consumption of 1600 lbs. of coke per ton of iron. Increased cheapness in the production of iron ore and of other products is also mentioned, and the great extension of labour-saving appliances and the reduction of the cost of labour by piece-work and profit-sharing schemes are also dealt with.

\* *The Engineering Magazine*, vol. xii. pp. 420-425.

† *Iron Age*, vol. lix. No. 8, p. 13.

‡ *Bulletin of the American Iron and Steel Association*, vol. xxxi. pp. 25-29.

§ *Journal of the Franklin Institute*, vol. cxliii. pp. 110-118.

**The Michigan Mining School.**—M. E. Wadsworth\* has published a paper on the elective system as adopted in the Michigan Mining School, which forms an interesting contribution to the study of technical education. In the engineering colleges of the United States two systems have been followed, namely: (1) that in which the students have to follow a fixed course, and (2) that in which freedom of choice is permitted. The latter system has been adopted at the Michigan School with marked success. In accomplishing the training of men to help in the development of the mineral wealth of the country, the school has endeavoured to reduce to a minimum all studies to be taken by every student, to preserve the sequence, and to obtain thorough work by the business method of individual responsibility. The only studies required of all the students are elementary geology and the principles of mining. Outside these subjects the student is allowed unrestricted freedom of choice in his studies. The elective system has been in use at the Michigan Mining School for some time, and while further experience will undoubtedly indicate various modifications of details, it can certainly be considered up to the present time an unqualified success.

The recently published annual year-book of the Michigan Mining School contains, besides the usual information regarding this prosperous institution and its courses of instruction for 1897-98, some valuable details of the copper and iron mining industries of the State. In very concise terms the more important facts regarding the various mines of the Marquette, Menominee, and Gogebic ranges are set forth. Thus, on the last-named range the Norrie Mine, it is stated, produces 800,000 tons of iron ore annually, and is the greatest iron mine in the world. The ore deposit is one mile long, and is reached by twelve shafts; 1300 men are employed. There are two winding engines with ten drums, Prescott pumps, electric signals and lighting, and timbering on the square-set system.

\* *American Geologist*, November 1896.

## XVI.—COMPARATIVE TABLES.

**The World's Production of Coal and Iron.**—For the purposes of comparison, the following summary of the production of coal in the principal countries of the world is appended:—

Country.	Year.	Production in Tons.
United Kingdom . . . . .	1896	195,361,260
Australia—		
New South Wales . . . . .	1896	3,909,516
New Zealand . . . . .	1895	740,827
Queensland . . . . .	1894	270,706
Tasmania . . . . .	1895	36,274
Victoria . . . . .	1895	197,343
Austria, coal . . . . .	1896	9,722,679
" lignite . . . . .	1895	18,389,147
Hungary, coal . . . . .	1895	1,068,046
" lignite . . . . .	1895	3,517,901
Belgium . . . . .	1896	20,457,604
Borneo . . . . .	1895	18,149
Canada . . . . .	1896	3,743,234
Cape Colony . . . . .	1895	87,985
Dutch East Indies . . . . .	1893	67,713
France . . . . .	1895	27,588,000
Germany, coal . . . . .	1895	79,169,276
" lignite . . . . .	1895	24,788,363
Holland . . . . .	1894	109,278
India . . . . .	1895	4,370,000
Italy, lignite . . . . .	1894	271,294
Japan . . . . .	1894	4,311,000
Labuan . . . . .	1895	40,614
Natal . . . . .	1895	160,115
Russia . . . . .	1895	9,725,000
Spain . . . . .	1895	1,774,560
Sweden . . . . .	1895	228,652
United States . . . . .	1896	168,956,972

A similar summary showing the production of pig iron is as follows:—

Country.	Year.	Production in Tons.
United Kingdom . . . . .	1896	8,563,209
Austria . . . . .	1895	778,510
Hungary . . . . .	1894	329,985
Belgium . . . . .	1896	932,780
Canada . . . . .	1896	60,030
France . . . . .	1896	2,333,702
Germany . . . . .	1896	6,374,816
Italy . . . . .	1895	9,213
Japan . . . . .	1894	15,760
Russia . . . . .	1895	1,454,298
Spain . . . . .	1896	246,326
Sweden . . . . .	1895	462,930
United States . . . . .	1896	8,623,127

A statement\* has been published as a Parliamentary paper, showing the production and consumption of coal and the number of persons employed in coal production in the principal countries of the world in each year from 1883 to 1895, as far as particulars can be stated. Lignite is also dealt with in an appendix.

**Iron Ore.**—J. M. Swank, the Secretary of the American Iron and Steel Association, has prepared an interesting pamphlet on the question of tariff revision, which contains many statistical tables relating to the iron and steel industries of the United States. The following valuable table, embodying the latest information available, is given, showing the world's production of iron ore in the year 1895:—

	Iron Ore. Tons.
United States . . . . .	15,957,614
United Kingdom . . . . .	12,615,414
Germany and Luxemburg . . . . .	12,349,600
France . . . . .	3,772,101
Belgium . . . . .	312,637
Austria-Hungary . . . . .	2,409,584
Russia . . . . .	2,487,225
Sweden . . . . .	1,904,662
Spain . . . . .	5,514,839
Italy . . . . .	183,371
Canada . . . . .	91,783
Other countries . . . . .	1,386,044
Total . . . . .	<hr/> 58,984,374

The figures showing the production of France and Russia refer to the year 1894.

A. POURCEL † briefly reviews the present distribution of the iron ore producing districts in the world, and gives sketch-maps of Europe, Asia, the United States, Australasia, Africa, and South America, with the principal districts indicated.

**Pig Iron Production.**—N. Kjellberg ‡ shows graphically the production of pig iron in the various countries from 1870 to 1894. During the quarter of a century the world's production has increased from 12·3 to 26·0 million tons. The share taken by each country was as follows:—

\* Coal Tables.

† *Revue Générale des Sciences*, 1896, pp. 510-515.

‡ *Teknisk Tidsskrift*, vol. xxvi. pp. 41-44.

Country.	1870.	1894.
	Per Cent.	Per Cent.
Great Britain . . . . .	48·8	29·0
United States . . . . .	14·1	26·2
Germany and Luxemburg . . . . .	11·4	21·4
France . . . . .	8·9	8·1
Russia . . . . .	3·0	4·7
Belgium . . . . .	4·5	3·5
Sweden . . . . .	2·4	1·8

Thus, in the twenty-five years, Great Britain, France, Belgium, and Sweden have lost ground, whilst the United States, Germany, and Russia have gained.

The total production of pig iron during the twenty-five years was as follows :—

Country.	Million Tons.	Per Cent.
Great Britain . . . . .	182·0	39·5
United States . . . . .	116·0	25·2
Germany and Luxemburg . . . . .	80·0	17·3
France . . . . .	41·0	9·0
Belgium . . . . .	16·5	3·6
Russia . . . . .	14·8	3·2
Sweden . . . . .	10·0	2·2
Total . . . . .	460·3	100·0

**World's Production of Steel.**—According to E. Schroedter,\* leaving out of consideration crucible steel, the world's production of steel ingots during the past year was as follows, in thousands of tons :—

United States . . . . .	5,600
Germany . . . . .	4,900
United Kingdom . . . . .	4,200
France . . . . .	1,128
Russia . . . . .	900
Austria-Hungary . . . . .	869
Belgium . . . . .	598
Sweden . . . . .	250
Spain . . . . .	105
Italy . . . . .	60
Canada . . . . .	40
Total . . . . .	18,650

\* "Die Bedeutung und neuere Entwicklung der Flussisenherzeugung." Dusseldorf : A. Bagel. 1897. *Revue Universelle des Mines*, vol. xxxviii. p. 210.

In order to obtain the total production of steel, there must be added to these figures 200,000 to 250,000 tons of crucible steel. This is made in England (100,000 tons), in the United States (70,000 tons), in Germany, France, Austria, and Russia.

Classified according to the mode of manufacture, the production of steel ingots in 1896 was as follows, in thousands of tons :—

Country.	Bessemer.		Open-hearth.	
	Acid.	Basic.	Acid.	Basic.
Germany . . . . .	351	3,005	184	1,294
United Kingdom . . . . .	1,380	465	2,180	175
France . . . . .	197	530	305	97
Austria-Hungary . . . . .	120	224	21	504
Belgium . . . . .	198	333	2	65
Sweden . . . . .	79	18	77	20
United States . . . . .	3,932	50	1,600	
Russia . . . . .	250	...	535	
Spain . . . . .	63	...	42	
Italy . . . . .	20	...	40	
Canada . . . . .	...	...	40	
Totals . . . . .	6,590	4,625	7,181	

**Shipbuilding in Germany and the United Kingdom.**—In 1896 there were built in Germany four fast passenger steamers of over 10,000 tons, while in the United Kingdom only one such was built; but, apart from this, the total German construction only amounted to about 107,000 tons, as compared with 1,316,906 tons built in the United Kingdom.\* In 1895 these totals were respectively 101,400 and 1,074,890. It will thus be seen that the out-turn of the United Kingdom showed an enormous increase as compared with the production in 1895. In only one year indeed (1889) has it been exceeded. In that year it amounted to 1,332,889 tons.

**Geological Surveys.**—E. A. Schneider † has collected some details regarding the cost of European geological surveys, and in this relation is also given a short history of the survey in each country, and other particulars of their proceedings and publications.

\* *Stahl und Eisen*, vol. xvii. pp. 203-204.

† *Engineering and Mining Journal*, vol. lxii. pp. 342, 366, 392.

**Death Rates in Mines.**—The following table\* gives the comparative death rates in mines in various countries :—

Country.	Description of Workings.	1894.		1895.	
		Under-ground only.	Total Under-ground and Surface.	Under-ground only.	Total Under-ground and Surface.
Austria . . .	Coal mines . . .	...	5·10	...	...
" . . .	Brown coal mines . . .	...	2·10	...	...
" . . .	Salt mines . . .	...	0·44	...	...
Belgium . . .	Coal mines . . .	...	1·62	...	...
" . . .	Ore mines . . .	...	1·36	...	...
" . . .	Quarries, underground . . .	...	0·17	...	...
Canada—					
Nova Scotia . . .	.....	...	...		1·73
Cape Colony . . .	Diamond mines . . .	16·02	7·34	7·34	3·79
France . . .	All mines . . .	0·96	0·84	...	...
" . . .	Coal mines . . .	0·96	0·85	...	...
" . . .	Other mines . . .	0·92	0·81	...	...
" . . .	All quarries . . .	...	1·41	...	...
" . . .	Underground quarries . . .	2·46	1·70	...	...
" . . .	Open quarries . . .	...	1·35	...	...
German Empire . . .	All mines . . .	...	1·88	...	2·12
Greece . . .	" . . .	...	1·48	...	...
Holland . . .	Mineral working other than mines . . .	...	21·76	...	...
India . . .	All mines and quarries . . .	...	2·53	...	...
Italy . . .	All mines . . .	...	1·30	...	1·60
Natal . . .	" . . .	...	...	...	4·31
New S. Wales . . .	" . . .	...	1·04	...	...
New Zealand . . .	" . . .	...	3·16	...	...
Portugal . . .	" . . .	...	0·59	...	...
Queensland . . .	" . . .	...	1·02	...	1·22
Russia . . .	" . . .	...	1·29	...	...
South African Republic . . .	Coal mines . . .	...	5·86	...	3·26
" . . .	Gold mines . . .	...	4·44	...	4·64
South Australia . . .	.....	...	...	...	2·90
Spain . . .	All mines . . .	...	2·27	...	1·92
Sweden . . .	" . . .	...	1·30	...	4·40
Tasmania . . .	" . . .	...	0·88	...	1·72
United Kingdom . . .	" . . .	1·79	1·59	1·66	1·49
" . . .	Coal mines . . .	...	...	1·60	...
United States . . .	Coal mines (total) . . .	...	2·36	...	...
Illinois . . .	" . . .	...	1·87	...	...
Kansas . . .	" . . .	...	2·52	...	...
Kentucky . . .	" . . .	...	1·26	...	...
Maryland . . .	" . . .	...	1·76	...	...
Michigan . . .	Iron mines . . .	...	3·00	...	...
Missouri . . .	Coal mines . . .	...	2·53	...	...
Ohio . . .	" . . .	...	1·43	...	...
Pennsylvania . . .	Anthracite mines . . .	...	3·19	...	...
" . . .	Bituminous coal . . .	...	1·42	...	...
West Virginia . . .	Coal mines . . .	...	2·98	...	...

\* *The Science and Art of Mining*, vol. vii. p. 257.

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